

**TEACHERS' MATHEMATICAL KNOWLEDGE FOR TEACHING
COMPUTER IN SELECTED SECONDARY SCHOOLS OF KASAMA
DISTRICT**

By

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**A dissertation submitted to the University of Zambia in partial fulfilment of the
requirements for the Degree of Master of Education in Mathematics Education**

THE UNIVERSITY OF ZAMBIA

Lusaka

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DECLARATION

I, **SERAH MULENGA**, do hereby solemnly declare that this dissertation represents my own work, except where otherwise acknowledged, and that it has never been previously submitted for a degree at the University of Zambia or any other University.

Signed: _____ Date: _____

APPROVAL

This dissertation of **SERAH MULENGA** is hereby approved as fulfilling the requirements for the degree of Master of Education in Mathematics Education by the University of Zambia.

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Chairperson Board of Examiners.....Signature.....

Date

Supervisor.....Signature.....Date:.....

DEDICATION

This work is dedicated to my late sister - mom ALICE MULENGA CHIBALE, may her soul rest in eternal peace.

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Firstly, I would like to thank my God almighty, for making this feasible at long last.

I thank Dr. Patricia Phiri Nalube my supervisor for having been so patiently assisting me and guiding me throughout this study.

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ABSTRACT

Mathematics is considered to be one of the most important school subjects in the curriculum worldwide. However, the pass rate for mathematics in Zambian secondary schools is very low. Reports have indicated that some of the challenges faced by candidates in mathematics could be attributed to pedagogical issues as well as lack of teaching and learning materials. In 2013 Zambia through the Ministry of Education Science, Vocational Training and Early Education (MESVTEE) revised the Zambian Education Curriculum which brought about the alignment of topics according to content and process domains and the introduction of new topics. Among the various topics introduced in mathematics, Computer and Calculator was one of them at both junior and senior secondary school levels. The first cohort to write the final examinations under the revised curriculum was the 2015 intake for grade 9s and the 2016 intake for grade 12s. Since then it has always been reported that candidates have continued exhibiting weaknesses in answering this topic (Computer). This study was therefore undertaken to explore teachers' mathematical knowledge for teaching computer and establish how it influences their instructional strategies. A sample of three teachers from three different schools were purposively selected and in order to probe deeply, analyse thoroughly and get an in depth and detailed understanding of the phenomena under review. The study adopted the qualitative research methods approach which followed a descriptive case study design. Data was collected using lesson observations, open-ended questionnaires and semi-structured interviews. Data was analysed thematically with the help of Ball et al (2008) domains of Mathematical knowledge for Teaching (MKT). Although, all the three teachers showed competences in teaching computer, some variations in terms of the depth of PCK were observed. Two of them made some minor mistakes when teaching the topic to grade 11 learners. Some of their mistakes noted in the topic were: incorrect use of elements of a flowchart (shapes), writing the formula in flowchart without showing operation signs according to computer demands, writing formula in flowcharts with ordinary multiplication and division signs, instead of a star (*) and slash (/) respectively, failure to properly guide learners on indenting, just to mention but a few. It was recommended that, Secondary schools should intensify School Based Continuing Professional Development (SBCPD) so that teachers of mathematics can share knowledge regarding teaching of the topic computer at secondary school level.

key words: Computer, Algorithms, Mathematical Knowledge for Teaching (MKT), Instructional strategies.

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ABBREVIATIONS AND ACRONYMS

CCK	Common Content Knowledge
CK	Content Knowledge
CPDs	Continuing Professional Development
ECZ	Examinations Council of Zambia
HK	Horizon Knowledge
KCC	Knowledge of Content and Curriculum
KCS	Knowledge of Content and Students
KCT	Knowledge of Content and Teaching
MC	Mathematical Challenge
MESVTEE	Ministry of Education Science, Vocational Training and Early Education
MKT	Mathematics knowledge for Teaching
ML	Management of Learning
MoE	Ministry of Education
PCK	Pedagogical Content Knowledge
SBCPD	School Based Continuing Professional Development
SCK	Specialised Content Knowledge
SCK	Subject Content Knowledge
SMK	Subject Matter Knowledge
SS	Sensitivity to Students
ZEEP	Zambia Education Enhancement Project

CHAPTER 1

1.Introduction

This study aims at exploring teachers' mathematical knowledge for teaching computer in selected secondary schools of Kasama district. The first chapter presents the background to the study, statement of the problem, purpose of the study, study objectives, research questions, significance of the study, scope of the study, limitation of the study, theoretical and conceptual frameworks, as well as the operational definition of terms.

1.1 Background of the study

Mathematics is considered to be one of the most important school subjects in the curriculum worldwide. It is the subject that plays a crucial role in aiding the mental processes that improve logical and critical thinking. Mathematics also is viewed not only in terms of obtaining an academic qualification at school or college but is also considered a subject that prepares learners for the future, regardless of the career path they choose to pursue (Davies & Hersh,2012). The Examinations Council of Zambia (ECZ) (2012, p.31) argued that “one of the objectives of teaching mathematics is to build up an understanding and appreciation of mathematical concepts and computational skills in the learners in order for them to apply them in other subject areas and everyday life”. Thus, knowing mathematics can be something satisfying and empowering because of some of the qualities that are fostered by the subject.

It is however, disheartening to note that despite mathematics being one of the most important subjects as well as one of the key subjects that is considered for admission of learners for most post-secondary school educational programs and with all the importance attached to mathematics in the Zambian education system, poor performance is recorded for several years (Changwe & Mulenga, 2018; ECZ, 2016). This poor performance in mathematics in Zambia and countrywide has called for most researchers to carry out studies in order to establish the possible causes. Sa'ad, et al (2014) found out that some of the causes of poor performance in mathematics are anxiety and fear of mathematics, inadequate qualified teachers, poor teaching methods and inadequate teaching materials. In Zambia, reports have also indicated that “Challenges faced by candidates in mathematics could be attributed to pedagogical

issues as well as lack of teaching and learning materials” (ECZ, 2016, p.18). This implies that teachers need to know beyond what they are required to teach and how to teach. They need to have vast content knowledge (CK) of the topics which they teach, that is when we can expect learners to do better in the topics and the subject as a whole (Shulman,1987). The primary purpose of teaching at any level of education is to bring a fundamental change in the learner (Tebabal & Kahssay, 2011). In order to achieve this, it is expected that a mathematics teacher should have the knowledge and a high level of understanding of the topic.

According to the *Zambian education policy document, Educating our Future* (MoE, 1996) it is explained that the essential competencies expected in every teacher are to master the subject matter to be taught and a skill in communicating that subject matter to the learners. Besides, Soer (2009) contended that teachers of mathematics should be in a position to communicate the required knowledge in a clear, informative and precise manner to their learners. This would eventually help learners to learn mathematics with good conceptual understanding rather than by memorization. Similarly, Ball et al (2008) described a kind of knowledge that every teacher of mathematics need in order to carry out their work and termed it as *Mathematical Knowledge for Teaching (MKT)*. Mathematical knowledge was described as substantive knowledge which comprised both conceptual and procedural understanding. It is obvious that teachers need to know the content they teach and that students are expected to master. Hill and Ball (2009, p.68) also argued that “Teaching mathematics requires specialized knowledge about the subject, which mathematicians don’t need”.

In 2013 Zambia through the Ministry of Education Science, Vocational Training and Early Education (MESVTEE) revised the *Zambian Education Curriculum* which brought about the alignment of topics according to content and process domains and the introduction of new topics. Among the various topics introduced in mathematics, Computer and calculator was one of them at both junior and senior secondary school levels. World over, there is a strong call for the general populace to be well vested with knowledge, skills and values of computers. As such, computers have become part and parcel of peoples’ lives and work in today’s world (MoE, 2011). As a skill-based topic, computer and calculator is designed to meet the needs of this modern world. It is also

believed that the 21st century is marked by the widespread use of algorithms, which help handle the large amounts of data generated every day. Emphasizing the importance of this topic is crucial, particularly for individuals striving to compete for jobs in a global market where employers emphasize essential skills for their workforce (Güven, 2008).

Computers has made us aware of the importance of algorithms but at the same time the dangers of continuing to behave in traditional ways (Kowszun & Higgo, 1986). This implies that while technology, like computers and algorithms, brings advantages, it is essential to be mindful of not blindly adhering to outdated methods without acknowledging the potential drawbacks or limitations. Algorithms is one of the concepts in the Zambian mathematics syllabus that every learner is expected to understand among other concepts in the topic computer. Learners are therefore, expected to show competence at the end of an instruction in the following; describing the components of a computer (i.e. Input, Process and output parts/devices), know various methods of implementing an algorithm (flowcharts and pseudo code) and outline problem solving stages (MESVTEE, 2013). According to Brousseau (1997) an algorithm is said to be a step by step procedure for performing a given task or solving a particular problem. This can either be in form of ordinary language (Pseudocodes) or boxes of various kinds joined together by lines (Flowcharts). In many cases, using an algorithm is appropriate; it saves time and prevents miscalculations. In this way, using algorithms provides learners with opportunities to solve tasks simply by reusing the procedure that a particular algorithm stands for. However, the use of algorithmic reasoning is, in itself, not an indication of one's conceptual understanding of mathematics (Haavold, 2011).

The first cohort of the grade 9s to write the final examinations under the revised curriculum was the 2015 intake whereas the first cohort of the grade 12s was the 2016 intake. Since then candidates have continued exhibiting weaknesses in answering questions on the topics such as Computer specifically on algorithms (flowcharts and pseudocodes) (ECZ,2016; ECZ, 2017; ECZ ,2019). For instance, questions 17 (b) on pseudocode and 3 (a) on flowcharts in mathematics paper 1 and 2 respectively recorded the following comments;

17(b) The general performance of this question was “poor” Most candidates did not attempt this question. Some who attempted it performed poorly ECZ (2016, p.107).

3(a) The general performance of this question was fair. However, there was failure to use correct flowchart symbols by some while others did not consider the decisions ECZ (2016, p .109).

In the general comment section, the following was indicated;

Candidates had challenges with some of the new topics like calculus (Integration and differentiation), computers (flowcharts and pseudo code), composite functions, equations of perpendicular lines, Relative and absolute error, Social and Commercial Arithmetic, sum to infinity of a G.P and trigonometric equation ECZ (2016, p.18).

In 2017, it was also revealed that most candidates just copied the given flowchart for the answer and some candidates failed to use the correct terminologies for the pseudo code like enter, “display error” (If, Then, Else, End If, Display....) ECZ (2017, p.59). From the above comments it is evident that learners have been facing challenges on this topic especially that it is newly introduced. This could be an indication perhaps that teachers have knowledge gaps in handling these topics owing to the fact that most of them were not adequately engaged in workshops on what is required of them to teach these topics (ECZ, 2019). Some teachers may have problems with Subject Content Knowledge (SCK) of these added topics while others may have the content knowledge but still struggle with the teaching Pedagogical Content Knowledge (PCK). It is also possible to find teachers who may have challenges in both SCK and the teaching (PCK) of the introduced topics in mathematics. Since teachers’ SCK and PCK are the major kinds of knowledge required for effective teaching and learners’ understanding, it is expected that teachers of mathematics should have sufficient SCK and PCK of this topic computer (Ball et al, 2008; MoE, 1996; Shulman, 1987).

Moreover, ECZ (2019) through the Zambia Education Enhancement Project (ZEEP) in their document titled “literature review of best practices to improve learner performance in Zambian schools” highlights that Mathematics teachers should possess the appropriate knowledge needed for teaching computer basics. Based on the above-

information, it may seem that most Mathematics teachers are experiencing some difficulties to teach computer. In addition, throughout the researcher's experience of being a Subject teacher of mathematics for four years, it was observed that some mathematics teachers struggle to make the content accessible to the learners in some topics especially the newly introduced ones.

The fact that candidates faced challenges on new topics, computers being among them in 2016 and the years that followed, it is important to ascertain what the problem really is (ECZ, 2019). It is against this background that this study seeks to explore teachers' mathematical knowledge for teaching computer by focusing on teachers of mathematics who were currently engaged in teaching the topic computer at selected secondary schools in Kasama district.

1.2 Statement of the problem

Computer and Calculator is one of the topics which was added to the mathematics syllabus following the Zambia curriculum revision of 2013. This introduction was necessitated by the fact that in this computer era learners in mathematics needed to have some basic ideas of what goes on in computer programming as that could prepare them to handle problems in this computer age (MESVTEE, 2013). However, it has been repeatedly reported that learners have continued failing this topic during the final examinations just like any other added topics in mathematics (ECZ, 2016). This poor performance by candidates in the final examinations could be an indication that perhaps teachers have problems in unpacking the topic to the learners.

Some studies have looked at teachers' subject matter knowledge and PCK in the topics that were recently added to mathematics syllabus D such as Calculus, Quadratic Equations and Geometrical Transformation (Mbewe, 2019; Mulenga, 2019; Simovwe, 2019). However, ECZ (2019) through the Zambia Education Enhancement Project (ZEEP) recorded that in mathematics at Grade 9 level only 25.70% of teachers exhibited mastery of subject content, meaning about 25.70 percent of learners were taught by teachers with desirable mastery of subject content. Moreover, these studies did not look at teachers' mathematical knowledge for teaching computer at senior level in Zambia. It is not known whether teachers of mathematics have the required knowledge for teaching the new topic computer. Hence, this study was focused on

exploring teachers' mathematical knowledge for teaching computer at senior level. Exploring teachers' mathematical knowledge for teaching computer would help to address the problems teachers encounter in teaching computer in mathematics, assess the instructional strategies and also help to determine measures that would bring about effective and efficient teaching of computer thus, enhancing learner learning of computer.

1.3 Purpose of the study

The purpose of this study was to explore teachers' mathematical knowledge for teaching computer at senior secondary school level.

1.4 Objectives of the study

The study was guided by the general and specific objectives

1.4.1 General objective

The general objective of this study was to explore teachers' mathematical knowledge for teaching computer.

1.4.2 Specific objectives

The study was guided by the following specific objectives:

1. To determine teachers' mathematical knowledge for teaching computer.
2. To explore the instructional strategies used by teachers in teaching computer.
3. To establish how teachers' mathematical knowledge for teaching computer influences their instructional strategies.

1.5 Research questions

The study was guided by the following research question:

1. What mathematical knowledge for teaching computer do teachers have?
2. What instructional strategies do teachers of mathematics use when teaching computer?
3. How do teachers' mathematical knowledge for teaching computer influence their instructional strategies?

1.6 Significance of the study

This study is significant because it was focused on teachers' mathematical knowledge for teaching computer. It explored teachers' SCK and PCK, and established how the two kinds of knowledge affected their teaching of computer. Thus, this study may contribute to the following if successfully carried out; it may help to highlight some inadequacies in the teaching of computer and that may benefit teachers of mathematics in their daily work. It may also inform teachers of good PCK if they are to improve learner performance in the subject. It may also inform the teacher educators on what to emphasise on regarding SCK and PCK when preparing prospective teachers of mathematics. It may also inform policy makers and curriculum developers on what aspects of teaching to consider when making educational policies and curriculum respectively, concerning teachers' SCK and PCK. Finally, the results might also add to the field of mathematics education research in the Zambian context since little is known about secondary teachers' mathematical knowledge for teaching the topic computer.

1.7 Delimitation of the study

Delimitations show how the study is narrowed in scope (Creswell, 1994). This study focused exclusively on public secondary schools within the urban areas of Kasama district, Zambia. The delimitation was set to include only schools that have implemented the recently introduced topic computers in their mathematics curriculum. Private schools and schools in rural areas were deliberately excluded from the scope of this study. This choice aimed to narrow the research focus to a specific context where teachers' mathematical knowledge for teaching computers can be thoroughly examined.

1.8 Limitations of the study

Limitations are the probable flaws in the study which are out of control of the researcher (Simon, 2011). This section outlines factors that may have affected the outcomes of this study in some way. To start with, the quality of technological infrastructure in schools, including access to computers and the internet, affected how teachers incorporated technology into their teaching. The researcher had no control over the level of technological support provided. Secondly, the study did not explore teachers' mathematical knowledge for teaching computer in relation to learners'

performance in the topic because of several external factors that come into play. For example, variations in students' preferred learning styles and cognitive abilities which could impact how they grasp Computer concepts, and Variations in students' socioeconomic backgrounds, including access to resources such as computers and a conducive learning environment at home, can impact their performance. These individual differences are beyond the researcher's control. Moreover, it was likely that the participants may be affected by the researchers' visit, by being anxious or unwilling to fully cooperate. The nature of the study also restricted the generalisation of the findings other than provision of insights into the mathematical knowledge for teaching computer. In the next section, I now discuss the theoretical and conceptual frameworks which guided this study.

1.9 Theoretical framework

This study was underpinned by Shulman's (1986) framework of Teacher Knowledge with an emphasis on Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). Shulman (1986) identified three categories of Teacher Knowledge, namely; *Subject Matter Knowledge (Subject Content Knowledge)*, *Pedagogical Content Knowledge* and *Curriculum Knowledge*. These are the types of knowledge that teachers may need to display as they teach and interact with their learners in the classroom. However, this study focused on two of the categories above, namely; Subject Matter Knowledge and Pedagogical Content Knowledge of which Ball et al (2008) termed as mathematical knowledge for teaching.

Shulman (1987) defines Content Knowledge (CK) as Knowledge of the actual subject matter to be learned or taught, while Pedagogical content knowledge (PCK) as the knowledge of how to teach within a particular subject area. In the context of this study, CK means teachers' knowledge of computer which includes; describing the components of the computer, definition of an algorithm and methods of presenting an algorithm (flowcharts and pseudocodes) while pedagogical content knowledge means knowledge of learning difficulties, knowledge of conceptions and misconceptions and knowledge of instructional strategies that is applicable and appropriate to teaching computer.

McNamara (1991) suggests that teachers with strong CK may teach in a more interesting and dynamic way whilst those with little CK may shy away from the more difficult aspects of the subject, or approach their teaching in a didactic manner. It is also argued that PCK enables teachers to ease the learning for learners through use of clear explanations, appropriate analogies and presenting learning in interesting, motivating and even entertaining ways (Shulman, 1987).

This framework therefore, was applicable to guide this study in that; i) Shulman's framework is seminal work for understanding teacher knowledge and ii) Shulman's categories of teacher knowledge relate to the two forms of knowledge that Ball et al (2008) termed as Mathematical Knowledge for Teaching (MKT) which this study was focused on. According to Ball et al (2008), subject content knowledge and pedagogical content knowledge are two kinds of knowledge that teachers of mathematics required to carry out their work of teaching. In this regard, Teachers of mathematics need these kinds of knowledge (SCK and PCK) to teach computer in order to avoid giving learners incorrect information, also help address and correct any existing misconceptions that learners could bring to the topic and preventing the development of further misunderstandings.

The two categories of mathematical knowledge for teaching are further divided into six domains (Ball et al, 2008). The common content knowledge (CCK), the specialised content knowledge (SCK) and horizon knowledge (HK) fall under subject matter knowledge while the knowledge of content and students (KCS), knowledge of content and teaching (KCT) and knowledge of content and curriculum (KCC) fall under pedagogical content knowledge. However, this study, focused only on CCK, SCK, KCT, and KCS as the other two domains HK and CK were seen to be embedded in some of the four domains for example, HK was seen in SCK through linking representation to underlying ideas and to other representations. This implies that, if the teacher has the capacity to represent computer concepts in different forms, he/she understands or is aware of a broad range of information, ideas, or possibilities related to the topic computer. As for the Knowledge of Curriculum which is the availability of materials that can be used to support student learning was also seen in Knowledge of Content and Teaching (KCT), where the teacher is required to sequence particular content for instruction, deciding which content comes first. According to Ball et al (2009; p .401) says that, "The lines between our four types of knowledge can be subtle.

For instance, recognizing a wrong answer is common content knowledge (CCK), while sizing up the nature of the error may be either specialized content knowledge (SCK) or knowledge of content and students (KCS)”. These domains were used as lenses in investigating the mathematical knowledge for teaching computer.

1.10 Conceptual framework

The diagram below is the conceptual framework showing the main assumptions of teachers’ mathematical knowledge for teaching computer in order to ensure that learners understand the concepts easily. This conceptual framework is an adaptation from the works of other scholars (Ball et al., 2008; Bair & Rich, 2011; Shulman, 1986; Steele et al., 2013). It was heavily influenced by ideas from the MKT framework of Ball et al (2008).

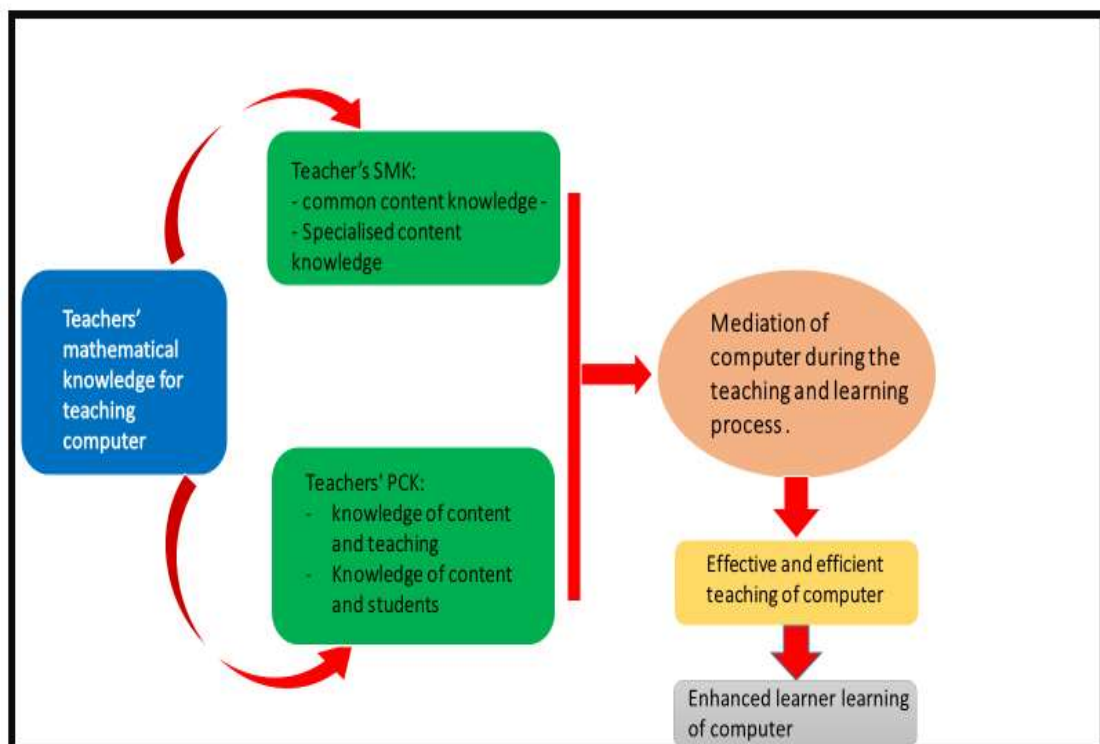


Figure 1: Conceptual framework adapted from Ball et al, (2008) model of MKT

The conceptual framework above shows that teachers’ mathematical knowledge of computer falls into SMK and PCK. When the teacher has these two categories of mathematical knowledge in computer that is when they can effectively mediate the concepts to the learners when teaching the topic. This is so because teaching begins with a teacher understanding of what is to be learned and how it is to be taught. It

proceeds through a series of activities during which learners are provided with specific instructions and opportunities for learning, though the learning itself ultimately remains the responsibility of the learners (Shulman, 1987).

Figure 1 therefore, implies that this study explored teachers' mathematical knowledge for teaching computer by looking at teachers' subject matter knowledge and pedagogical content knowledge which is necessary for them to provide mediation of the concepts to the learners. Only when teachers' SMK and PCK in computer is adequate can we expect effective and efficient teaching of computer to take place and enhanced learner learning in computer.

1.11 Operational definitions of key terms

In this study concepts were defined operationally, according to the context in which they were used.

Mathematical knowledge for teaching: Ball et al (2008, p.4) defined MKT as “mathematical knowledge that teachers need to carry out their work as teachers of mathematics”. further, mathematical knowledge is described as substantive knowledge which comprised both conceptual and procedural understanding. In the context of this study, the term Mathematical Knowledge for Teaching means the teachers' mathematical understanding needed to teach computer. This includes; posing questions, interpreting learners' answers, providing explanations, and using representations.

Subject Content Knowledge: In the context of this study, SCK means teachers' knowledge of computer which includes; describing the components of the computer, definition of an algorithm and methods of presenting an algorithm (flowcharts and pseudocodes).

Pedagogical Content Knowledge: knowledge of learning difficulties, knowledge of conceptions and misconceptions and knowledge of instructional strategies that is applicable and appropriate to teaching computer.

Instructional strategies: the specific methods and approaches employed by teachers to facilitate the learning of the topic computer in mathematics.

Mediation: according to Vygotsky's (1987) concept of mediation, it is a process through which the social and the individual mutually shape each other. In the context of this study mediation means the tools and signs that the teacher uses to direct and guide the learning discourse of computer (how teachers of mathematics help learners learn better by interacting with them).

Algorithm: Set of step-by-step instructions that perform a specific task or operation

Flowchart: is a graphical representation of a process

Pseudocode: Set of instructions that mimic programming language instructions

1.12 Summary of the chapter

The aim of this study was to explore teachers' mathematical knowledge for teaching computer. The rationale for the study was based on learners' poor performance of mathematics in general and in particular computer. The study was informed by Shulman's (1986) framework of Teacher Knowledge with an emphasis on Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). Furthermore, the study was important to be carried out because it may help to highlight some inadequacies in the teaching of computer and that may benefit teachers of mathematics in their daily work. The chapter that follows focusses on reviewing of related literature.

CHAPTER 2

REVIEW OF RELATED LITERATURE

2.1 Overview

This chapter presents a review of literature on teacher knowledge, mathematical knowledge for teaching which gives an understanding of what kind of knowledge a teacher of mathematics requires in relation to computer, the importance of computer (algorithms) in mathematics and the related studies with gaps identified.

2.2 Conceptualisation of Teacher knowledge

In the early history, assessing teacher knowledge has been a subject of interest for decades among educators with more emphases placed on the teachers' Subject Matter Knowledge (SMK) (Ball et al, 2005; Ma, 1999; Saxena 2015). This entails principles and concepts of the content. Teacher knowledge is important as multiple strands of evidence support the notion that what a teacher knows impacts the quality of classroom instruction and hence student learning (Chan, 2019). Later in the mid-eighties, it was realised that there was a missing paradigm in teaching thus, the word Pedagogical Content Knowledge (PCK) which simply means the blending of pedagogical knowledge and content knowledge. Shulman (1986) indicated that PCK is an important province of knowledge within the professional base of teachers that is most germane to teaching. He further stated that "the teacher need not only understand *that* something is so; they must further understand *why* it is so" (Shulman, 1986, p. 9). In this study, this means that other than understanding the concepts in computer, teachers of mathematics need to further explain as well as to justify reasoning for effective and efficient teaching of computer. PCK According to Gess-Newsome (2015, p. 36) includes the knowledge and skills needed for a teacher to teach a "particular topic in a particular way for a particular purpose to particular students for enhanced student outcomes".

This kind of knowledge (PCK) differentiates between a qualified teacher and an unqualified teacher in the sense that qualified teachers are trained on how to make the subject matter comprehensive to the learners through teaching methods, while the unqualified teachers are not (Shulman, 1986; Shulman, 1987). It is in this vain that

Shulman proposed the model of teachers' knowledge that should be displayed by the teachers as they interact with the learners in the classrooms for effecting teaching and learners' understanding. Shulman's (1986) model of teachers' knowledge is divided into three main subcategories; Subject Matter Knowledge, Pedagogical Content Knowledge, and Curriculum Knowledge. Shulman's initial PCK ideas led many researchers to advance his ideas by coming up with different PCK models (Ball et al., 2008; Gess-Newsome, 2015; Grossman, 1990; Magnusson et al, 1999). Below is the framework of teacher knowledge for Shulman (1986);

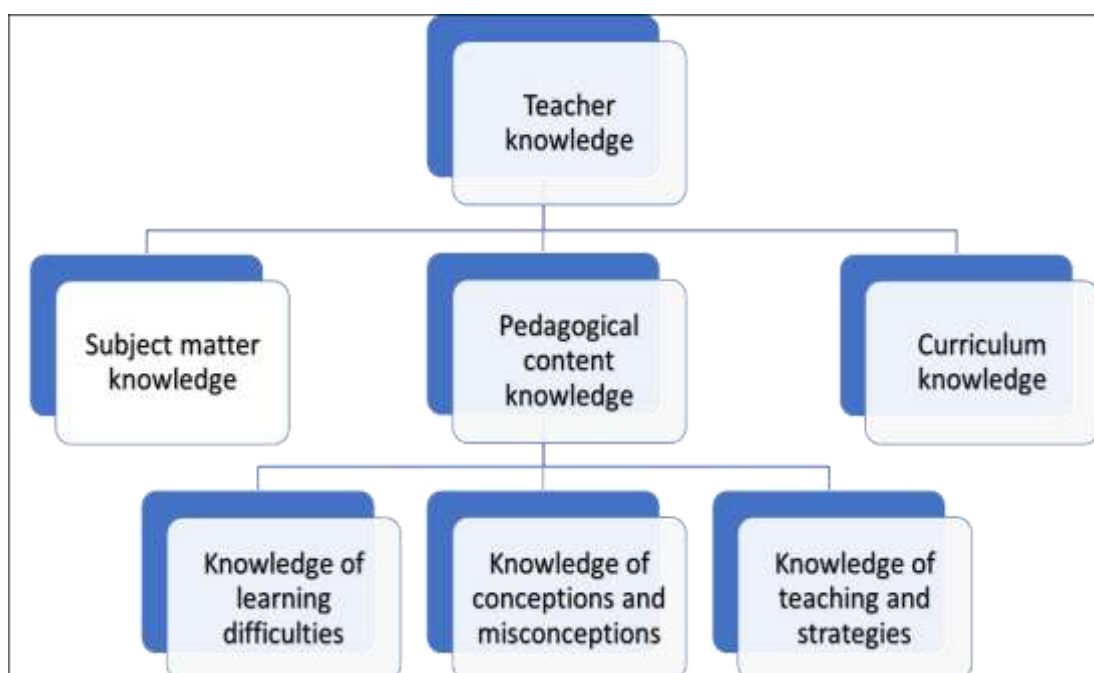


Figure 2: Model of Teacher Knowledge (Shulman, 1986) adopted from (Kandjinga, 2018, p.14).

Further, Shulman (1987) categorised the knowledge base for teaching as follows;

Table 1: Shulman's Major Categories of Knowledge base for teaching

- Content knowledge
- General pedagogical knowledge, with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter
- Curriculum knowledge, with particular grasp of the materials and programs that serve as "tools of the trade" for teachers
- Pedagogical content knowledge, that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding

- Knowledge of learners and their characteristics
- Knowledge of educational contexts, ranging from workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures
- Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds

(Shulman, 1987, p. 8)

According to Shulman, table 1 shows at minimum what teacher knowledge would include if they were to be organised in a certain way. Among the categories, Pedagogical content knowledge is pronounced and arguably most influential because it identifies the distinctive bodies of knowledge for teaching that is content and pedagogy (Shulman, 1987).

The importance of teachers' professional knowledge as an indicator of teachers' competencies is emphasised by different authors. For instance, according to the Zambian education policy document, *Educating our Future* (MoE, 1996) it is explained that the essential competencies expected in every teacher are to master the subject matter to be taught and a skill in communicating that subject matter to the learners. In this study, teachers of mathematics are then expected to be competent in computer and have a skill to communicate the concepts in computer to learners.

Saxena (2015) also regard CK and PCK as the crucial kinds of knowledge that lead to effective teaching and learners' understanding of the subject matter. According to Ding et al. (2014, p. 52), "content knowledge is grounded in the core teaching activities and influence teachers' decision making about content-specific instructions such as designing a task on posing a meaningful question for students' explorations". It is therefore, important that this study seeks to establish how teachers' mathematical knowledge for teaching (MKT) computer influences their instructional strategies.

With the similar sentiments, Kathirveloo et al (2014, p.1) states that "Pedagogical Content Knowledge (PCK) plays an important role in classroom instructions. In the teaching and learning process, PCK involves teachers' competence in delivering the conceptual approach, relational understanding and adaptive reasoning of the subject matter". Hassen (1995) adds as cited in Kathirveloo et al (2014) that it is important for a teacher to be capable of transforming the knowledge to be taught to the learners in a way that could be understood easily. This means that teaching computer should not

only be about the teacher demonstrating how to get the correct answer, but the teacher should also find ways of how to mediate computer during the teaching and learning process so that learners understand the concepts in computer with ease. This is what Shulman (1987) was trying to mean by PCK as earlier defined.

Despite the fact that SMK and PCK are usually treated as two separate categories, the interrelationship between the two is very important especially for the subject of mathematics (Ding et. al, 2014; Shulman, 1986). Shulman (1986) also postulated that content knowledge is as important to the preparation of a teacher as pedagogical knowledge and emphasized that the two constructs needed not to be studied as isolated components. Although not a focus of this study, a growing body of research shows that learners' performance is more heavily influenced by the teacher's quality in terms of content knowledge and pedagogy knowledge than by learners' prior academic record or school a student attended (Ishola & Udofi, 2017). This shows how important subject matter knowledge is to teaching.

2.3 Mathematical Knowledge for Teaching (MKT)

Since the conception of the teachers' knowledge model by Shulman (1986), various researchers have modified Shulman's original model of teachers' knowledge, by either making SMK as a subcategory of PCK or either adding new dimensions (Ball, et al 2008; Danişman and Tanişli 2017; Tatto et al. 2012). The field of mathematics is one of the fields that has recorded substantial research to investigate the kind of knowledge required for teaching mathematics. The MKT model by Ball and others is therefore, of central importance to this study with an emphasis on SMK and PCK. According to Ball et al (2008) it was observed that in the past, there was a focus on what teachers needed to know which had led to a set of positions, each related to principled arguments about what teachers should know. They further added that the prevailing view was that teachers need to know whatever mathematics is in the curriculum plus some additional number of years of further study in college mathematics.

The other assumption was that teachers need to know the curriculum, plus some amount of pedagogical content knowledge. It was therefore concluded that in both cases, the question of what makes up the extra knowledge of mathematics was unclear (Ball et. al, 2008; Steele, 2012). Thus, their approach to studying mathematical

knowledge for teaching. Ball et al (2008, p.4) defined MKT as “mathematical knowledge that teachers need to carry out their work as teachers of mathematics”. She further, described this mathematical knowledge as substantive knowledge which comprised both conceptual and procedural understanding. It is obvious that teachers need to know the content they teach and that learners are expected to master. Their work was focused on the following; what teachers do in teaching mathematics, what they need to know, what teachers need to do in teaching mathematics by virtue of being responsible for the teaching and learning of content and how does this work demand mathematical reasoning, insight, understanding, and skill? (Hill et. al, 2009). To illustrate this a model for mathematical knowledge for teaching was formulated as shown below.

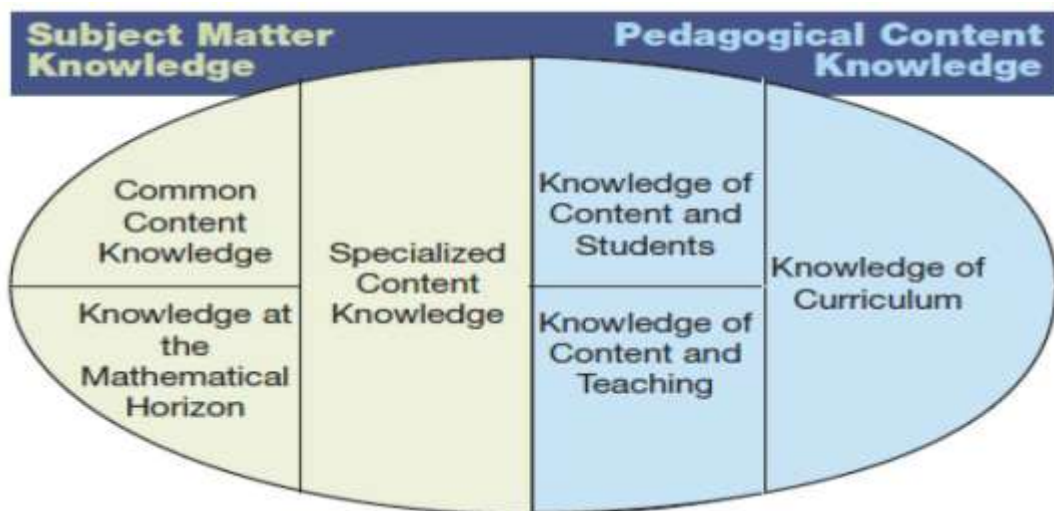


Figure 3: Aspects of mathematical knowledge for teaching (Ball et al. 2008)

Building on Shulman’s (1986) call to attend to the intersections between pedagogical and subject-matter knowledge, Ball et al (2008) describe six aspects of mathematical knowledge for teaching (MKT), shown in the figure above. Under Subject-matter knowledge, there is common content knowledge (CCK) the ability to use mathematics to solve problems. This knowledge is certainly prerequisite to being able to teach mathematics (Steele et al, 2013). In this study, teachers need to know all the concepts that are needed for the learners to understand computer. Beyond CCK, Teachers also need to know how to represent mathematics content in ways that support student learning of mathematical ideas that is specialised content knowledge (SCK). Studies

have demonstrated the importance of this specialized content knowledge (SCK) in teachers' abilities to plan, teach, and reflect on practice, such as anticipating student thinking, identifying and addressing mathematical misconceptions or confusions, and making decisions while teaching (Carpenter et al. 1989; Stein et al,1990; Sherin 2002; Nalube, 2011; Steele, 2013).

In the context of this study SCK was conceptualized in two categories; capacity to represent computer concepts in different forms, and aptitude to explain as well as to justify reasoning. The following descriptors were then defined for the above sub-categories of SCK; presenting an algorithm in form of a flowchart and a pseudocode, working with different computer notations, and translating between representations. The second category, was defined by providing mathematical explanations for common rules and procedures in computer, recognizing and explaining conceptual differences and relationships, explaining the understanding of the key terms such as a Flowchart, Algorithm and Pseudocode, and justifying rules and use of specific methods (Hill et al, 2009; MESVTED, 2013).The third domain under Subject Matter Knowledge is the Knowledge at the mathematical horizon, this is the understanding of the broader set of mathematical ideas to which a particular idea connects (Ball et al, 2009). However, as already argued in Section 1.9, this domain could be embedded in SCK. Hence HK is not directly focused on in this study.

Pedagogical content knowledge, on the other hand was sub-divided into knowledge of content and students (KCS), knowledge of content and teaching (KCT) and Knowledge of curriculum (KC). Ball and Bass (2009) describes KCS as a blend of teachers' knowledge of mathematics subject matter and that of learners' difficulties, errors and misconceptions. The teacher develops knowledge of understanding learner mathematical characteristics that would help them learn effectively. KCS enables teachers anticipate, identify and resolve learners' misconceptions about mathematics. KCT refers to a blend of teachers' knowledge of mathematics subject matter and pedagogy (Ball et al , 2008; Even, 1990; Kathirveloon et al, 2013). This means teachers need to know a variety of teaching approaches and methods that would help in the effective teaching of mathematical concepts. Having this kind of knowledge equips teachers with the ability to use appropriate teaching strategies in the delivery of concepts (Carpenter et. al. 1989; Nalube, 2011). Last but not the least, Knowledge of

Curriculum is simply knowing about the curriculum. In this study, it implies ways to sequence and structure the development of the topic Computer, including representations likely to help pupils learn. Ball et al, (2008) include this domain in a figure in their paper but never describe it explicitly. They do, however, mention about knowledge of content and curriculum to imply that teachers need knowledge of the available materials they can use to support student learning. However, Knowledge of Curriculum is not explicitly focused on in this study because it is considered to be imbedded in KCT.

There have been several issues however, regarding Ball's et al (2008) model in the way the domains are defined, that it has limitations. Some of these issues have been raised by Ball et al (2008) themselves. Firstly, while Shulman's work was based on logical assumptions, MKT is a theory that was framed solely on practice (; Ball et. al, 2008; Shulman, 1986; Von Christopher, 2018).

Secondly, both boundaries and relationships among the MKT domains remain unclear. As explained by the proponents of MKT themselves, there continues to be a difficulty in discerning common knowledge from specialized knowledge. The distinction between these two domains seem to be clearly defined, however, under which category can knowledge be placed that is neither common to those outside the profession nor specialized to what we must know as teachers of mathematics? (Hill et al, 2008). Furthermore, explanations about the relationships between any of the two domains are deficient. It is not clear if the domains exist independent of each other or if they complement each other such that improving one domain leads to a significant gain in knowledge of another.

In theory, when teachers teach, all their abilities that stem from these domains blend with each other to produce the form of instruction they deliver. This idea presents a concept of an interplay among domains, e.g. how a knowledge of content and students reinforces (KCS) knowledge of content and teaching (KCT) an interesting facet of the theory that remains to be unelaborate in the framework. Furthermore, the difference among the domain areas in the framework (see Figure 3) has been left unclear whether devoting a larger area for SCK and KC means that these are more important, more complicated, or more apparent in what composes teacher knowledge (Ball et. al, 2008; Hill et. al, 2009; Von Christopher, 2018).

Despite these concerns, ideas of the MKT framework resonated well with the objectives of this study in the sense that these ideas have relevance to what teachers ought to understand to be effective in teaching computer.

2.4 Importance of computer in mathematics

Computer is a topic which was added to mathematics syllabus following the Zambian curriculum revision of 2013. This topic was added to both the junior and senior secondary school syllabi. These syllabi seek to instil a sense of appreciation of technology education to ensure that learners adapt and cope with changing situations. The syllabi also provide learners with broader concepts and principles in technology, which allow them to expand their thinking capacity to tackle real life situations effectively. World over, there is a strong call for the general populace to be well vested with knowledge, skills and values of computers. As such, the importance of introducing computer in mathematics cannot be overemphasised.

Computer has made us aware of the importance of algorithms but at the same time of the dangers of continuing to behave in traditional ways (Kowszun, & Higgo, 1986). Algorithms is one of the concepts in the Zambian mathematics syllabus that every learner is expected to understand among other concepts in computer. Learners are therefore, expected to show competence at the end of an instruction in the following; demonstrating the components of a computer, various methods of implementing an algorithm and outline problem solving stages (MESVTEE, 2013). An algorithm is a set of instructions that describes how to get something done and they are usually designed using pseudocode and flowcharts (Brousseau, 1997).

A flowchart is just a drawing that uses shapes and lines to show how the different stages in a process are connected to each other (Haavold, 2011). This means that, a flowchart lets one to leverage the visual part of the brain to ‘see’ how the algorithm functions. Charntaweekhun and Wangsiripitak (2006) emphasizes the significance of flowcharts in programming, particularly in the context of Visual Programming using Flowchart. The authors, advocates for the efficacy of flowcharts in simplifying the programming process and enhancing understanding. Emphasizes the fundamental symbols in a basic flowchart, including process, flow line, decision, connector, start & stop, input/output, and subroutine symbols.

Each type of symbol in a flowchart conveys different meanings corresponding to their specific functions, for example; Process Symbol: Represents a statement, Input/output Symbol: Signifies a variable name, Decision Symbol: Indicates a condition, Start Symbol: Represents parameters, and Stop Symbol: Denotes a return value. The significance of each symbol is conveyed through the text it contains. Therefore, it is important to accurately represent text and other properties when drawing a flowchart. (Ensmenger ,2016; Charntaweekhun & Wangsiripitak ,2006)

A Pseudocode on the other hand allows one to ‘get the ideas down’ as step by step code-ish statements. For example, getting to the one correct answer to a math problem challenges many learners who may not know where to start or how to get to the answer (Brousseau, 1997; Frost, 2020). Further, Frost (2020) argued that, flowcharts provide a framework for the math process, giving learners a step-by-step approach to tackling the problem. It is therefore, important to teach learners how to read flowcharts so they can integrate them into the mathematics curriculum for improved problem solving. Algorithms are also used in many branches of science and everyday life for that matter, but perhaps the most common example is the step-by-step procedure used in long division (Morley, 1981).

Much time in mathematics classes is spent learning and rehearsing algorithms, which are supposed to provide learners with a quick and reliable way to cope with many of the tasks ahead (Boesen et al., 2014; Hiebert, 2003). Allowing a child to creatively invent ways of resolving problems is known as developing algorithmic thinking. When teachers watch learners do their mathematics, a great question to pose to them is "Can you think of a shorter way to do that?" Allowing children to create their own methods to resolve issues stretches their thinking and analytical skills (Manning, 1984; Morley, 1981). In short, everything that one does in life requires an algorithm.

2.5 The teaching triad

According to Jaworski (1994) Mathematics teaching in the classroom involves the creation of opportunities for learners to learn mathematics. Elements of this include; providing a supportive learning environment, offering appropriate mathematical challenge and nurturing processes and strategies which foster learning. As a result of extensive observation of mathematics classrooms, Jaworski introduced what is called the *teaching triad* which is a synthesis of three elements above, as a means of describing mathematics teaching.

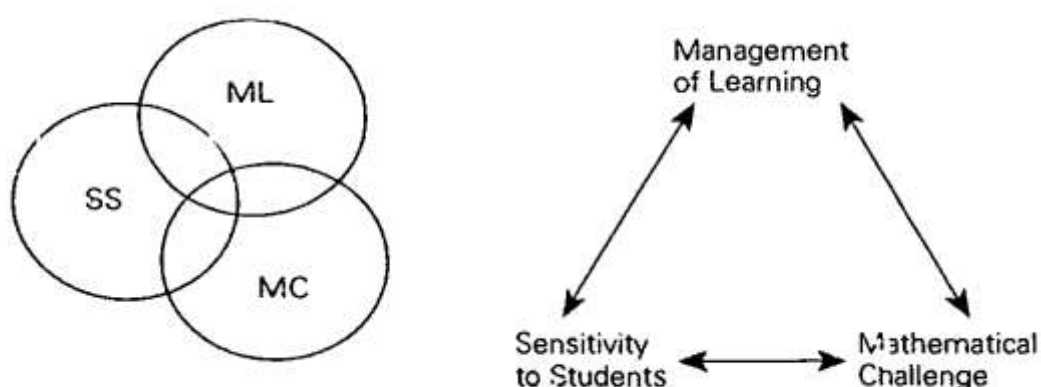


Figure 4: *The teaching triad (Jaworski, 1994)*

In the context of this study, the three elements were incorporated in the domains of MKT and used to describe the teaching of computer when observing teachers of mathematics. The three domains had connections linking to both SMK and PCK. Therefore, the essence of teaching computer may also be seen to lie in three domains; the management of learning (ML), sensitivity to students (SS) and mathematical challenge (MC). Management of learning is said to manifest in a set of teaching strategies and beliefs about teaching which influences the prevailing atmosphere and the way in which the lessons are conducted, sensitivity to students is inherent in the learner-teacher relationship and the teacher's knowledge of individual students and mathematical challenge arises from the teachers own epistemological standpoint and the way in which the teacher offers mathematics to the learner. The three are interrelated in any teaching situation (Jaworski, 1994).

2.6 Related studies and implications

Mathematical Knowledge for Teaching (MKT) plays a pivotal role in shaping instructional strategies in mathematics education. This specialized form of knowledge, as proposed by Shulman (1986) and later refined by Ball et al. (2008), encompasses both subject matter knowledge (SMK) and pedagogical content knowledge (PCK). The influence of MKT on instructional strategies is profound and multifaceted, impacting various aspects of teaching and learning in mathematics.

According to Ball et al (2008), teachers with a robust MKT exhibit enhanced clarity and organizational skills in presenting mathematical concepts. Their deep understanding of the subject matter allows for a coherent structuring of content, making complex ideas more accessible to students. This clarity contributes to a more effective transfer of knowledge during instruction. This also means that, MKT equips teachers with the ability to adapt instructional strategies to cater to the diverse needs of students. Teachers with strong MKT can tailor their approaches, fostering a more inclusive and responsive learning environment (Hill et al., 2009). With the inclusion of topics like computer, teachers with a strong MKT can effectively integrate technology into instructional strategies, enhancing students' digital literacy (Ball et al., 2008; ECZ, 2016). In addition to that, several studies in the area of mathematics have shown that pedagogical content knowledge, especially at senior secondary school level remains overwhelmingly teacher-centered with greater emphasis being placed on lecturing and textbook than on helping learners think critically across subject areas and applying their knowledge to real world situations (Butty,2001; Kanjinga, 2018).

Ma's (1999) study also highlights the implicit relationship between teachers' mathematical knowledge and their instructional practices. The study, titled "Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States," was a comparative examination of mathematics teaching in China and the United States. Ma's study underscored the critical role of teachers' deep subject matter knowledge in shaping their instructional approaches. The study revealed that teachers who possessed a profound understanding of the mathematical content were more likely to employ effective teaching methods. This highlights the inherent connection between a teacher's own grasp of mathematical concepts and their ability to convey those concepts to students. Beyond subject matter

knowledge (SMK), Ma's work also emphasizes the importance of pedagogical content knowledge (PCK). The study revealed Teachers who not only knew the mathematics but also understood how to facilitate student learning demonstrated more effective teaching strategies. The study illustrates different ways in which PCK informed instructional decisions, from choosing examples that resonate with students to anticipating common misconceptions. Ma's work advocates for a holistic view of teacher expertise, recognizing that effective teaching in mathematics is a product of the dynamic interaction between the teacher's mathematical knowledge and their pedagogical capability.

In addition to Ma's study, in relation to the influence of teachers' mathematical knowledge for teaching and their instructional practices; Hiebert and Grouws (2007) investigated the impact of mathematics teaching on students' learning outcomes, with an emphasis on the role of teachers' mathematical knowledge. This comprehensive review emphasizes the crucial role of teachers' content knowledge in shaping instructional strategies. The study suggests that effective teaching is closely tied to teachers' depth of understanding in mathematics. Further, Hill et al. (2005) delve into the relationship between teachers' mathematical knowledge and student achievement. The study emphasizes that teachers with higher MKT tend to employ more effective instructional strategies, leading to improved student performance. These studies collectively contribute to the understanding that teachers' mathematical knowledge, both in terms of content and pedagogy, plays a crucial role in shaping effective instructional strategies and positively impacting student learning outcomes.

Another study by Kandjinga (2018) investigated grade 12 teachers' subject and pedagogical content knowledge of Mathematics. It was found out that Grade 12 Mathematics teachers in the Khomas Education Region had a satisfactory SMK but limited to a certain extent, while their PCK of Mathematics was insufficient. The study also investigated the relationship between teachers' SCK and PCK, and their qualifications. No clear relationship was established between the Grade 12 Mathematics teachers' knowledge (SCK and PCK) and their teaching qualifications. Further, Kathirveloon et al. (2014, p. 1) highlights that "without full grasp of PCK, teachers may face difficulty in teaching the subject effectively. This is another indication that Lack of PCK will influence teacher's effective teaching and learning process in the classroom. A teacher is a person who is entrusted to enhance students'

learning. Thus, the teachers should be free of misconceptions and errors. In order to carry out their duties well they need particular and special knowledge that PCK suggests. Pedagogical Content Knowledge (PCK) plays an important role in classroom instructions. These studies however, did not look at teachers' subject matter knowledge and pedagogical content knowledge of computer in particular and how that influences their instructional strategies.

In Zambia, recent reports from the Examinations Council (ECZ) consistently highlight challenges in learners' performance, particularly in topics such as computer. ECZ (2019) through ZEEP found computers as one of the new topics which was challenging for learners as well as teachers at junior secondary. It was observed that some learners were not able to present the correct order of the strategies in a pseudo code and further suggested that learners require appropriate orientation to the correct steps concerning the pseudo code which can also be extended to the concept of flowcharts. It was also continuously noted in examiners' reports that the performance of many candidates in mathematics was generally poor and some candidates scored low marks in grade 12 final examinations, especially in algorithms (flowcharts and pseudocodes) and others left such questions unanswered (ECZ, 2015; ECZ,2016; ECZ, 2017).

A qualitative case study by Mulenga (2019), in selected schools of Lusaka district highlights the kind of knowledge teachers of mathematics have and the challenges they face when teaching Geometrical Transformations. Findings indicate that teachers had some incompetence's in some six domains of the mathematical knowledge for teaching Geometrical Transformations. The findings of this study however, cannot be generalised to other topics in mathematics.

Drawing from the above literature, Teachers' mathematical knowledge for teaching significantly influences instructional strategies. Global studies, including those in Zambia, underscore the importance of MKT in addressing the challenges posed by new and complex topics such as computer, functions, and calculus. As education evolves, understanding and enhancing teachers' MKT remains crucial for effective mathematics instruction and fostering improved student outcomes in Zambia and globally. It was therefore the researchers' concern to explore teachers' mathematical knowledge for teaching computer at senior secondary school level especially that in the Zambian context little is known about the teaching of computer.

2.7 Summary of the chapter

This chapter presented a number of issues arising from literature review on the: conceptualization of teacher knowledge according to Shulman (1986) and the mathematical knowledge for teaching as described by Ball et al (2008) and by different authors. It is said that the teacher need not only understand that something is so; they must further understand *why* it is so. Different authors have also argued about the kind of knowledge the teacher needs in order to teach mathematics effectively and the ways of characterising teaching of mathematics. The chapter also discusses the importance of teaching computer in mathematics and the relationship of MKT and instructional strategies. In all the studies highlighted in this chapter, what comes out is that a number of studies focused on either SMK and/or PCK in relation to learners' performance but not the teachers' mathematical knowledge for teaching computer. This study aimed to investigate teachers' knowledge of computer topics among those currently engaged in teaching computer and to understand how this knowledge influence their instructional strategies. The following chapter discusses the research methodology that guided this study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses methods and procedures which were used to collect the necessary information to achieve the research objectives. It follows the following format; the research paradigm, design, study area, population, study sample, and sampling techniques. Further, it describes the data collection procedure, instruments that were used, how the data was analyzed and interpreted, credibility and trustworthiness of the research and ethical considerations.

3.2 Research paradigm

This study employed an interpretive paradigm (Creswell, 2003). The interpretive paradigm was used because this study was concerned with understanding the phenomena of teachers' mathematical knowledge for teaching computer through observing, interviewing them and asking them questions that did not require a yes or no response. Interpretivists believe that there is no single correct route or particular method of knowledge. This paradigm emphasizes the importance of examining the world from participants' point of view as they believe that both knowledge and reality are constructed and reproduced through communication, interaction, and practice (Tracy, 2013).

3.3 Research design and approach

Research design is defined as a framework of methods and techniques chosen by a researcher to combine various components of research in a reasonably logical manner so that the research problem is efficiently handled. In this study it provided insights about how to explore teachers' mathematical knowledge for teaching computer using a particular methodology (Jackson, 2006). Additionally, Kombo and Tromp (2006) defines a research design as a "glue" that holds all the elements in a research project together, to show how all of the major parts of the research project work together to try to address the central research questions.

Considering the interpretive position adopted in this study and the nature of the research questions, the case study design was used because it provides a systematic way to collect data, analyse information and report results, thus that helped in understanding the case of teachers' mathematical knowledge for teaching computer in great depth. More specifically, it provided a variety of participant perspectives and allow the researcher to use multiple data collection techniques. Merriam (1998, p.28) asserted that "a case study is appropriate when a researcher's goal is to gain insights, discovery and interpretations of a particular phenomenon".

This study adopted the qualitative research methods approach because of its ability to probe deeply, analyze thoroughly and get an in depth and detailed understanding of the phenomena under review (Creswell, 2017). Following that the researcher intended to get closer to the teachers and collect data through interviewing and observing them in a natural setting, qualitative research approach best suited the carrying out of this research. Qualitative approach emphasizes the qualities of entities, processes and meanings that are not experimentally examined or measured in terms of quantity, amount, intensity or frequency (Denzin & Lincoln, 2000).

3.4. Study Area

This research was conducted in Kasama District of Northern province of Zambia particularly at three selected secondary schools. The three schools were selected based on different factors like the availability of computers in schools, and the research time frame and data accessibility. Msabila and Nalaila (2013) indicates that there are many motivating factors that could influence the researchers' choice of the study site, such as; the nature and incidence of the problem, research time frame, and data accessibility, clients' interest and instructions, resource availability, performance in particular field, goals and objectives of the study.

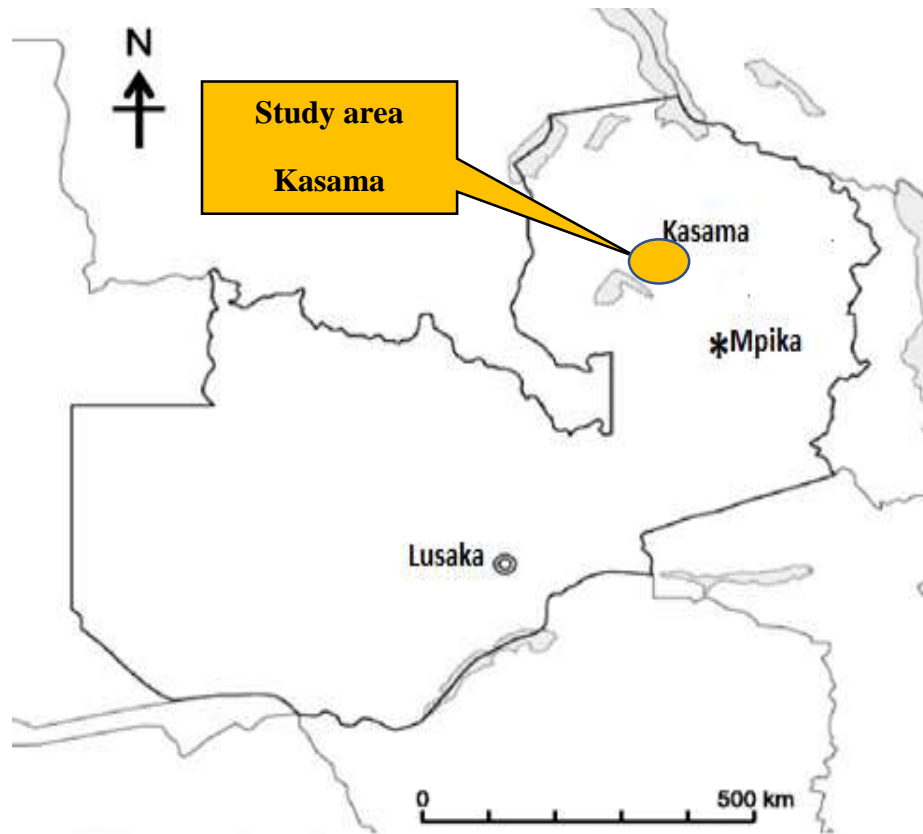


Figure 5: Map of Zambia showing the location of Kasama in Northern Province

3.5. Study Population

Population is defined as a group of individuals and objects from which samples are taken for measurement (Kasonde-Ng'andu, 2013). The population for this study consisted of all teachers of mathematics from three selected secondary schools in Kasama District, Northern Province.

3.6. Study Sample (size)

Kothari (2011) indicates that sample size refers to the number of participants selected from the population with common characteristics, know-how and accessible to help in the study under investigation. Sandeloski (1995) however, points out that in determining the sample size in qualitative research, there is no specific formula. It is ultimately a matter of judgment and experience on the part of the researcher, and researchers need to evaluate the quality of the information collected in light of the uses to which it will be applied. Therefore, in this study the researcher used personal judgment to determine the sample size. Furthermore, Cohen and Marrison (2000)

explain that in a qualitative study, a small sample size suffices. In view of the above, this study comprised of three teachers of mathematics from three different selected secondary schools, one teacher at each school. The sample size was considered in order to carry out an in-depth analysis and in a case of three schools, this was to uncover a variety of information about teachers' mathematical knowledge for teaching computer. Having provided the study sample for this study, the researcher now discusses the sampling techniques in the next section.

3.7. Sampling Techniques

Sampling techniques are classified into non-probability and probability. However, this study employed a non-probability sampling technique with the intention of selecting individual participants for the sample that does not give all the individuals in the population equal chances of being selected (Msabila & Nalaila, 2013). Purposive sampling was employed to purposely handpick individuals from the population based on the researcher's knowledge and judgment (Msabila & Nalaila, 2013). In particular, this study applied the homogeneous type of purposive sampling (Kombo & Tromp, 2006). The choice of teachers was based on those with shared characteristics and only teachers of mathematics that would be teaching computer at that time were sampled.

Further, Black (1999) argues that, purposive sampling ensures that those people who are unsuitable for the sampling study are already eliminated, so only the most suitable candidates remain. This method helped the researcher to carefully select people who were the best fit for the research. Thus, ensuring that the data collected directly addressed the research questions and it enhanced the validity of the study.

3.8. Data Collection Instruments

Research instruments are tools that researchers use in collecting the necessary data. In view of this, primary data was collected using lesson observations, semi-structured interviews, open-ended questionnaires. Primary data is data which is undocumented and is collected for the first time by the researcher.

3.8.1 Questionnaire

The study used an open-ended questionnaire to assess teachers' mathematical knowledge for teaching computer. It comprised open-ended questions coupled with

some content and pedagogy questions about the topic. This type of questionnaire was used because it allowed the respondents to express themselves freely thus providing more options and opinions, giving the data more diversity than would be possible with closed questions. See Appendix 4 for details.

3.8.2. Lesson Observations

According to Kothari (2004), under observation method, the information is sought by way of investigator's own direct observation without asking from the respondent. Morrison (1993) notes that, observations enable data collection by researchers from four areas: the physical setting, the human setting, the interactional setting, and the programme setting. This study used a lesson observation schedule containing the four domains of mathematical knowledge for teaching namely; common content knowledge (CCK), specialised content knowledge (SCK), knowledge of content and students (KCS) and knowledge of content and teaching (KCT). These domains of MKT resonated well with the objectives of this study because their ideas have relevance to what teachers ought to understand to be effective in teaching computer. Teachers' different competences were observed and noted in each lesson for the entire period the topic was taught.

The schedule also contained the domains of the teaching triad as a way of characterising the teaching of computer. According to Jaworski (1994), the essence of teaching mathematics may be seen to lie in three domains; management of learning (ML), sensitivity to students (SS) and mathematical challenge (MC). The triad helped the researcher to identify the teaching strategies specific to computer and overall describe each teacher's teaching. A total of 10 lessons were observed, for example, $T_X A$ was observed 4 times, $T_Y B$ was observed 4 times, and $T_Z C$ was observed 2 times. Of the 10 lessons observed, 8 of them were of the duration 80 minutes and 2 were of the duration of 40 minutes. All the lessons were recorded for the researcher to have a record of the data. Refer to Appendix 5 for the lesson observation schedule.

3.8.3. Semi Structured Interviews

One -to -one interviews were used to collect data from teachers. The semi- structured interviews were used because this gave the researcher an opportunity to seek both clarification and elaboration on issues raised by the interviewee. It also gave the

researcher 'latitude to probe' further and gather more information regarding teachers' understanding of computer and their instructional strategies as observed in the lesson (Deetz,1996). The interviews were semi- structured meaning some questions were prepared in a form of an interview guide prior to the interviews which was used as a basis for conversation. Some were drawn from the teachers' responses. As it is argued by Tuckman (1994, p. 366) that, "events cannot be understood unless one understands how these events are perceived and interpreted by people who participate in them". Follow up questions were asked on some of the things that were not clear in a questionnaire and during the lesson observations. The interviews were recorded in order to keep a record for purpose of data analysis and capturing data in its totality. See Appendix 6 for detailed interview schedule.

3.9. Data Collection Procedures and Time Line

Data collection was undertaken over a period of four months and the procedure was as follows: A questionnaire was administered to the selected teachers in order to determine the kind of knowledge teachers have for teaching computer. This was followed by lesson observations then semi structured interviews. Lesson observations were conducted before Interviews so that it does not give them a clue of what the researcher would be looking for as that can affect the way they would perform in class. Lesson observations also helped the research to determine the teachers content knowledge of computer in the way he/she was explaining concepts in computer to the learners, in the ability to identify errors and in the instructional strategies specific to computer. The interviews allowed the researcher to have some understanding over the issues that were raised in the questionnaire and during lesson observations.

3.10 Data analysis instruments and procedures

Data analysis can be viewed as a way of processing data so that what has been learnt can be disseminated to others (Corbetta, 2013). It involves the search for meaning within the collected data. In order to analyse data, this study used thematic analysis. Thematic analysis involves identifying, analyzing, and reporting themes or patterns within the qualitative data that are important or interesting (Braun & Clarke, 2006; Hall, 2004; Maguire & Delahunt, 2017). Creswell (2014) also asserted that, thematic analysis categorizes related topics, and major themes are identified to provide rich

deep description of the phenomena under study, therefore, data from semi-structured interviews, lesson observations and questionnaire was closely examined to identify common themes.

Data analysis started during the collection exercise by arranging the data collected in line with research objectives. Below is the table of how the researcher went about the analysis as adapted from Braun and Clarke (2006) followed by an explanation.

Table 2: *Braun and Clarke's (2006) six- phase framework for doing a thematic analysis*

Steps	Activity
1	Become familiar with the data
2	Generate initial codes
3	Search for themes
4	Review themes
5	Define themes
6	Write-up

The researcher first familiarized herself with the data collected from all the three instruments, this is the stage where transcribing took place. The data was analyzed vertically according to each instrument and horizontally across all the research instruments in line with the research questions. Secondly, initial codes were generated manually by identifying links between categories, grouping them thematically and sorting them according to different levels of generality in order to come up with a hierarchy of main and subthemes. After reviewing the themes, some sub-themes collapsed into other sub-themes whereas other sub-themes were broken down into smaller components.

Table 3 below shows an integration of the domains of mathematical knowledge for teaching (MKT) and the teaching triad as used in the study. Although, the domains are analytically distinct, they feed and inform each other.

Table 3: Indicators of MKT domains and the teaching triad

Categories	Domain	Indicators
<p>Subject content knowledge (SCK)</p>	<p>Common content knowledge (CCK)</p>	<ul style="list-style-type: none"> - Definition of concepts in computer - Recognize inaccurate definition from textbooks - knowing when learners' have answers wrong. - Correct use of terms and notations for computer when speaking and writing at the board.
	<p>Specialized content knowledge (SCK) & Mathematical challenge (MC)</p>	<ul style="list-style-type: none"> - Sizing up the nature of the error - Aptitude to explain as well as to justify reasoning (provision of mathematical explanations for common rules and procedures in computer, recognizing and explaining conceptual differences and relationships, explaining the understanding of concepts, Justifying rules and use of specific methods). - Capacity to represent computer concepts in different forms - Connecting a topic being taught to topics from prior or future Years -Using mathematical notation and language and critiquing its use
	<p>Knowledge of content and students (KCS) & Sensitivity to students (SS)</p>	<ul style="list-style-type: none"> -Type of examples given - Familiarity with learners' errors. - Ability to hear and interpret students' emerging and incomplete thinking. - Interaction between specific mathematical understanding and familiarity with learners' and their mathematical thinking.

<p>Pedagogical content knowledge (PCK)</p>	<p>Knowledge of content and teaching (KCT) & Management of learning (ML)</p>	<ul style="list-style-type: none"> - design specific instruction for computer. - Remediating learners' errors. - Instructional strategies when teaching a specific concept. - Sequencing of particular content for instruction - Controlling disruptive behaviors - Establishing classroom rules to keep activities run smoothly -Interaction between specific mathematical understanding and an understanding of pedagogical issues that affect student learning of computer.
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In analyzing data thematically within the context of the study, the indicators of Mathematical Knowledge for Teaching (MKT) domains offered a structured lens through which to understand the subtle differences of teachers' practices. The three domains proposed by Ball et al. (2008); Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), and Knowledge of Content and Students (KCS) can be related to Jaworski's teaching triad. The CCK and SCK align with the subject matter knowledge aspect of the teaching triad, encompassing what teachers need to know about the content they are teaching. On the other hand, KCS bridges into the relationships and interactions within the teaching triad, capturing how teachers integrate knowledge about their students with the content. Examining data through the MKT domains and the teaching triad allowed for a holistic understanding of how teachers' knowledge influences their instructional strategies. The triad emphasized the interplay between subject matter, pedagogical knowledge, and knowledge of students, while MKT domains offer specific indicators to delve deeper into each dimension, providing a comprehensive framework for thematic analysis in this study.

Table 4: *An example of how themes were generated*

Open-ended questionnaire	Lesson observation	Semi-structured interviews
$T_X A$, defines the term algorithm. (1)	$T_X A$, identifies when a pupil makes mistake. (1)	$T_X 1$, I use the main words/ key words; ENTER, IF...THEN...ELSE (2)
$T_X A$, gives the correct name for the symbols in Q 11. (1)	$T_X A$, not consistent with how to write a pseudocode. (1) (3)	$T_Y 2$, for the flowchart I go straight in introducing the boxes. (2)
$T_Y 2$, defines the term algorithm. (1)	$T_Z 3$, represents concepts in real life situation. (1)	$T_Y 2$, I start with flowcharts and then pseudocode. (2)
$T_Y 2$, fail to give the correct name to some symbols. (1)	$T_Z 3$, well defined terms and elaborated. (1)	$T_Y 2$, I emphasize that each statement should be in one box, no box should contain more than two statements. (2)
$T_Z 3$, lists down the pre-requisite knowledge for teaching and learning computer. (1)	$T_Y 2$, does not respond to some questions on pseudocode. (1)(3)	$T_Z 3$, am not sure how to go about a pseudocode, it does not have a standardized layout like the way a flowchart is. (1)
$T_Y 2$, writes the wrong formula for area of a cone. (1)	$T_Y 2$, uses the wrong boxes when drawing a flowchart. (1)	$T_Z 3$, there are just few instructions that I follow on how to indent; when a set of instructions are given on the same aspect, it means those set of
$T_X 1$, explain in a way that will involve day to day activities. (2)	$T_X 1$, defines the term “Looping” with a clear mathematical example. (1)	
$T_Y 2$, emphasize on repeated actions. (2)	$T_X 1$, justifies the use of some notations in a flowchart. (1)	

	<p>$T_X 1$, does not give chance to pupils to explain their answers. (1)</p> <p>$T_Z 3$, state common rules for writing a pseudocode. (2)</p> <p>$T_Y 2$, uses > as a guide when indenting in a pseudocode. (2)</p> <p>$T_X 1$, work given not organized. (3)</p>	<p>instruction should start on the same column. (2)</p> <p>. Other things fall on what is called ‘SELECTION’. (2)</p> <p>$T_Y 2$, I just teach two concepts flowcharts and pseudocode according to what comes in the exam. (3)</p> <p>$T_Y 2$, I just go through different past papers because the questioning is the same; I just teach for them to pass not understand. (3)</p> <p>$T_Z 3$, It is challenging to explain some concepts when you have not understood fully. (3)</p> <p>$T_Y 2$, some concepts are difficult to explain to pupils so I just give them the basic, and emphasize on what comes in an exam. (3)</p>
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Key: (1) – code answering RQ 1 (2) – code answering RQ 2 (3) – code answering RQ 3

In this study, themes were generated through a rigorous exploration of teachers' instructional practices and their mathematical knowledge for teaching computer. For instance, by closely observing teachers' approaches to explaining computer concepts, a theme emerged regarding variations in their content understanding and instructional strategies. This theme helped explore how teachers' mathematical knowledge, especially in areas such as algorithmic reasoning and flowchart representation, influences the clarity and effectiveness of their instruction. Through this detailed exploration, distinct themes related to the alignment (or misalignment) of MKT domains and their impact on instructional strategies were identified and analyzed systematically.

3.11. Trustworthiness

Trustworthiness is all about establishing the credibility, transferability, conformability and dependability of the study (Holloway, 1997). In order to ensure this, participants' own words, snapshots of teachers were used in the presentation of findings so as to prove to readers that the findings are real. During repeated observation, trust was built with participants. Triangulation was used to show the credibility of the findings by the use of multiple methods (see Section 3.8) in order to develop a comprehensive understanding of teachers' Mathematical knowledge for teaching computer. Cohen et al. (2007) described triangulation as the use of two or more methods of data collection in the study of some aspects of human behavior. The study also used inquiry audit in order to establish dependability which requires an outsider to person to review and examine the research process and the data analysis in order to ensure that the findings are consistent and can be repeated.

3.12. Ethical considerations

Ethical considerations are matters which are highly sensitive to the rights of others (Cohen, et al, 2000). This is an important aspect in establishing trust between the participants and the researcher. In this regard, ethical considerations were upheld in the study. First and foremost, a clearance letter was obtained from the Directorate of Postgraduate Studies and the researcher had to seek consent from the University of Zambia ethics committee (see Appendix 7). Secondly, the researcher sought permission from the District Education Board Secretary (DEBS) to allow access to

conduct the study in the schools. The researcher also ensured that participation by the teachers was voluntary which was done by explaining to them the procedure, relevance and benefit (as mentioned in Section 1.9) and purpose of the study. The participants were therefore, assured that data to be collected was to be kept confidential, their names and personal details were not going to be revealed or published, and that their participation would not affect their position or standing in school. The findings were also going to be used for research purposes only.

Ultimately, the researcher took full responsibility for the study and any unforeseen consequences it may have attracted. All the mentioned activities were done in order to ensure that the rights of the participants were respected and their dignity as human beings was safeguarded. The next chapter presents the findings of this study.

3.13 Summary of the chapter

In a nutshell, this chapter outlined and described the methodology used in the study. The study used an interpretivist research paradigm, and a descriptive case study design following the qualitative approach. Purposive sampling, homogenous in nature was used to select a total of 3 participants from different schools who participated in the study. Data collection was done by observing teachers first, followed by conducting interviews with them, then administering an open-ended questionnaire. Data analysis was done thematically. Credibility and trustworthiness were ensured by the supervisor and colleagues. They cross-examined the data and ensured that themes generated aligned with the study. Trustworthiness was also ensured by using participants own words; writings; snapshots of what transpired during teaching; and excerpts from documents in the presentation of findings as well as by triangulation. To adhere to ethical considerations, permission was sought from the various authorities and from the participants. The next chapter serves to present the study findings according to the research questions.

CHAPTER 4

FINDINGS

4.1 Overview

The previous chapter outlined the methodology used in the collection of data. Chapter four presents the research findings on teachers' mathematical knowledge for teaching (MKT) computer. Data was obtained from three teachers of mathematics at three different schools. The first set of data was collected using an open-ended questionnaire. This was followed by lesson observation then lastly the interviews. The findings are presented according to the research questions of the study. The research questions were as follows:

1. What mathematical knowledge for teaching computer do teachers have?
2. What instructional strategies do teachers of mathematics use when teaching computer?
3. How do teachers' mathematical knowledge for teaching computer influence their instructional strategies?

In this presentation of findings, the following codes have been used for identification of the participants. $T_X A$ (Teacher X at school A), $T_Y B$ (Teacher Y at school B) and $T_Z C$ (Teacher Z at school C). The research findings are evidenced by excerpts and snapshots.

Demographic characteristics of the teachers

Information about the teachers who participated in the study was obtained from the open-ended questionnaire (see Appendix 4). All the three were secondary school teachers, each of them taught for different years. One teacher taught for 8 years, the other for 15 years and the last one for 26 years.

4.2 Research question 1: What mathematical knowledge for teaching computer do teachers have?

Research question one focused on the mathematical knowledge for teaching computer that teachers of mathematics have. The information on this research question was

obtained from all the three instruments mentioned in Section 4.1. Themes emerged according to the domains.

4.2.1 Common Content Knowledge (CCK)

The following themes emerged from this domain;

4.2.1.1 Well and clearly defined concepts

From the questionnaire and a series of lessons observed, all three teachers were able to give accurate definitions with illustrations. This is noticed clearly in the following snapshots and excerpts.

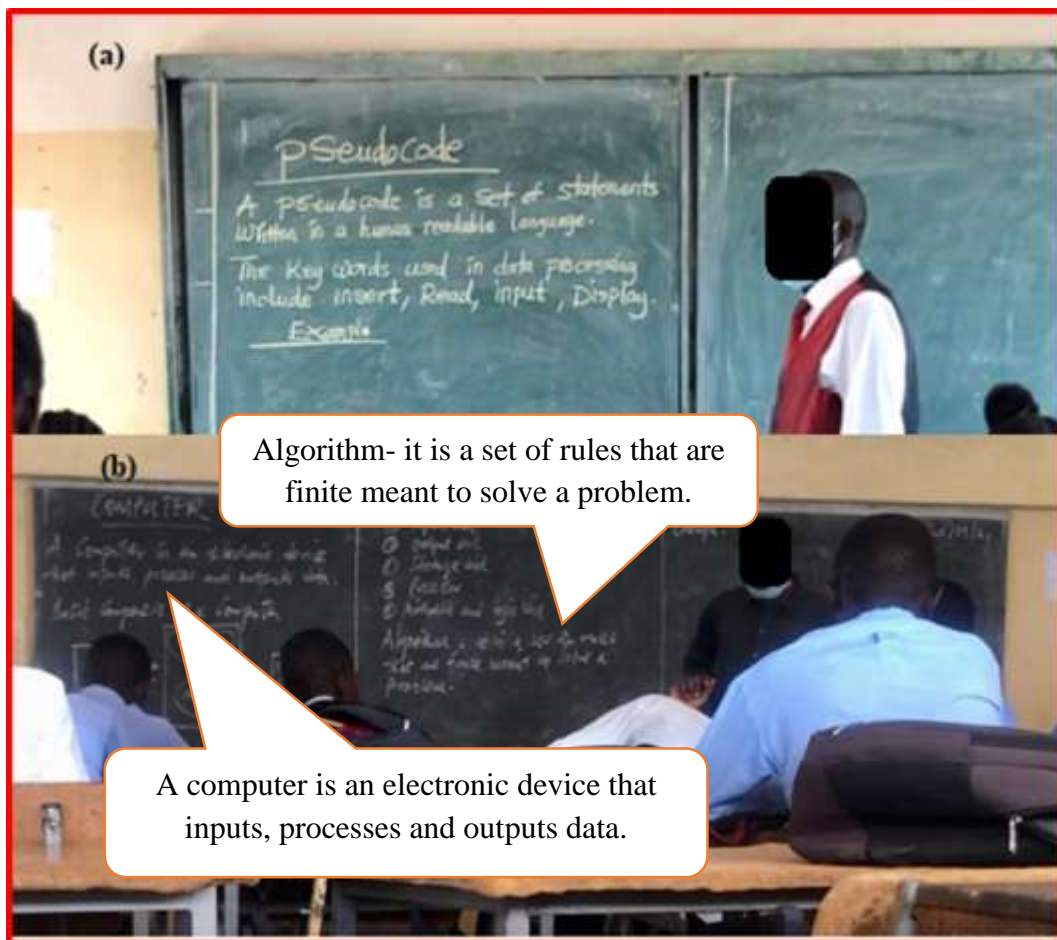


Figure 6: Shows $T_Y B$ in (a) and $T_Z C$ in (b) defining some of the concepts on the board

The following are the excerpts of teachers (**T_Y B** and **T_Z C**) respectively, giving illustrations by explaining the meaning of the definitions as shown in Figure 6 above;

T_Y B; *Today we are looking at another method on how you can solve a problem in form of what we are calling now a pseudocode.*

Learner; *a pseudocode?*

T_Y B *yes!! So, a computer has special language which it uses...this language for example, as human beings ourselves it is very difficult to understand that language of a computer. Now this pseudocode..., a pseudocode is a set of statements written in human readable language. So, to simplify that language from the computer, this language has to be written in form of human language which we can read...*

T_Y B *actually, the word pseudo means something which is not real, something fake, like those nick names you give each other (teacher points at the learners) can be called pseudo names. The same way you give us teachers nick names!!*

The key words used in data processing when using pseudocodes, we use words like insert, read, input, display and so on and so forth..

T_Z C; *The first aspect that we will need to look at under computer is an algorithm, have we heard of such a thing? (teacher asks learners)*

Learners (most of them); *no!*

T_Z C; *okay we will look at its actual definition later on.... but assuming that you want to come to school C starting from , lets say you stay in Tazara and you want to get to School C. you need to ask somebody who has been to School C they will give you steps/direction of how to move.... Now those set of instructions must be in a logical manner such that when you follow like that, you will find yourself at School C. that in a general term, we can call it as more less like an algorithm.*

Teacher continues to say;

So coming to a computer, a computer works with sets of instructions... computer ngamwayashafye ifi then mwalalolela, pali efyo yalamipela?(Translated as; if you turn on the computer and just leave it like that, will it give you anything?)

Learners; *AWE (no)*

T_Z C; it will switch on yes, but it will not be able to give you anything until you begin to give it instructions and these instructions must be logical and must not be perpetual. So, a computer works with algorithms, an algorithm is simply a set of instructions which are finite.

From the questionnaire, the teachers were also able to give accurate definitions.

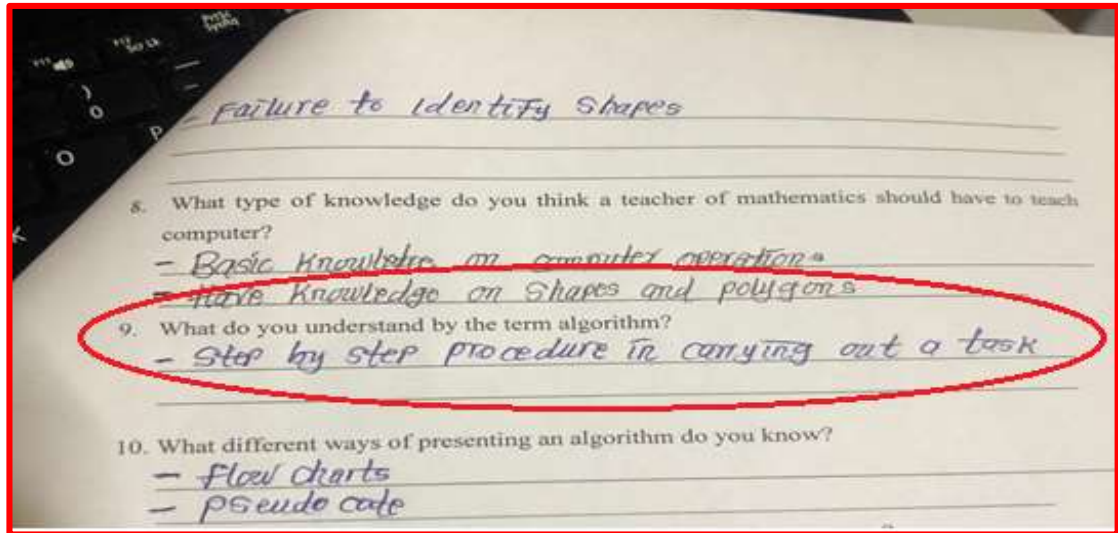


Figure 7: Sampled questionnaire for *T_X A* showing the definition of an algorithm

4.2.1.2 Use of terms and symbols

Results from the questionnaire and lesson observations revealed that one teacher out of the three was unable to give correct names for some symbols used in a flowchart. The teacher was also not using some symbols accurately when writing on the board. The figure below shows an incorrect name given by *T_Y B* and an inaccurate use of the boxes respectively.

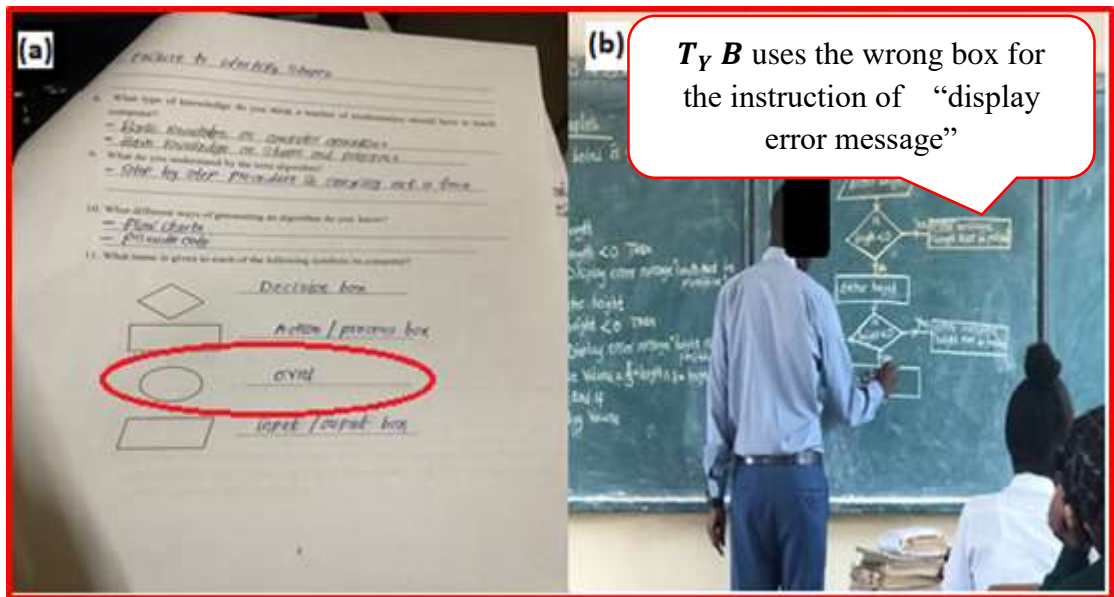


Figure 8: Showing wrong use of terms in (a) and wrong use of boxes in (b) when writing on the board

Below is an excerpt of **T_Y B** talking when answering a question on the board as shown in Figure 8 (b);

..lets now draw a corresponding flowchart for the given pseudocode. we first draw a start shape/box, then enter length in an input box, then arrow ,...is length less than 0 ? we put in a decision box ,if yes, we draw a process box and write display error message ...if not, we go on , we enter height (teacher enters h in a wrong box),,, is h less than 0 ? we put in a decision box , if yes we display error message as before (teacher repeats the mistake)

In an interview, when the teacher was asked to explain what he was trying to do in the first lesson, it was revealed that the teacher partially knew the uses of some symbols in a flowchart. The following excerpt shows the conversation of the researcher and the teacher.

Researcher: take me through the lesson...what were you trying to do here? (The researcher shows the video to the teacher)

T_YB: here I was just introducing the sub-topic flowcharts, where I explained the terms and symbols used in drawing a flowchart.... For example, a diamond is used when you are deciding.....

Researcher: what about this box? (a parallelogram)

$T_Y B$: that is an input box used for entering instructions.

4.2.1.3 Error recognition

Results from lesson observations revealed that two teachers were able to recognize errors from text books and know when learners made errors. $T_X A$ was able to identify errors in some learners' work when marking. $T_Z C$ also spotted when learners had answers wrong when responding to the questions through question and answer.

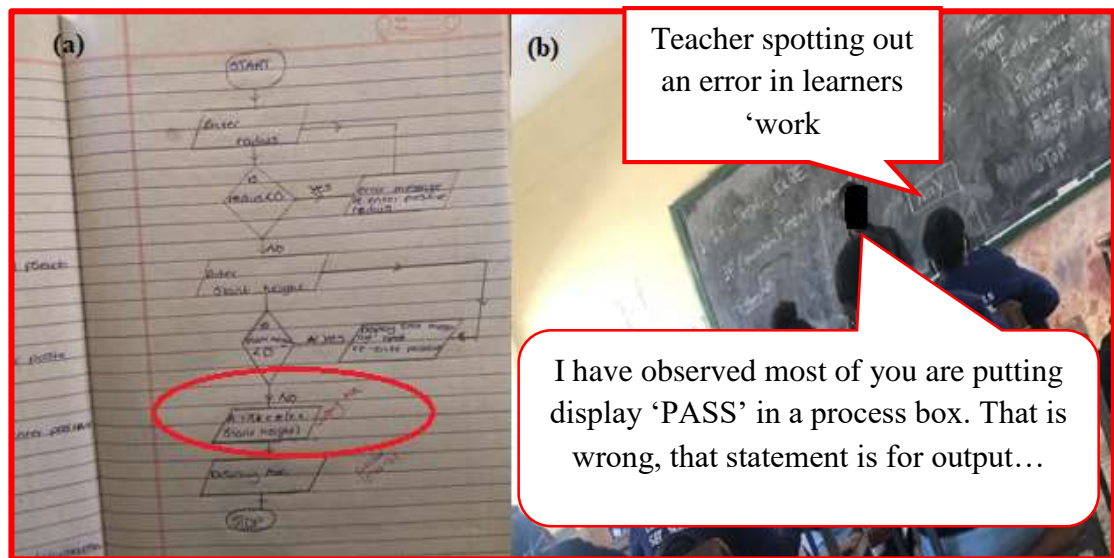


Figure 9: showing $T_X A$ recognizing an error in learners' answers in different lessons

However, $T_Y B$ was not able to recognize whether or not a past paper had errors as evidenced in the following snapshot;

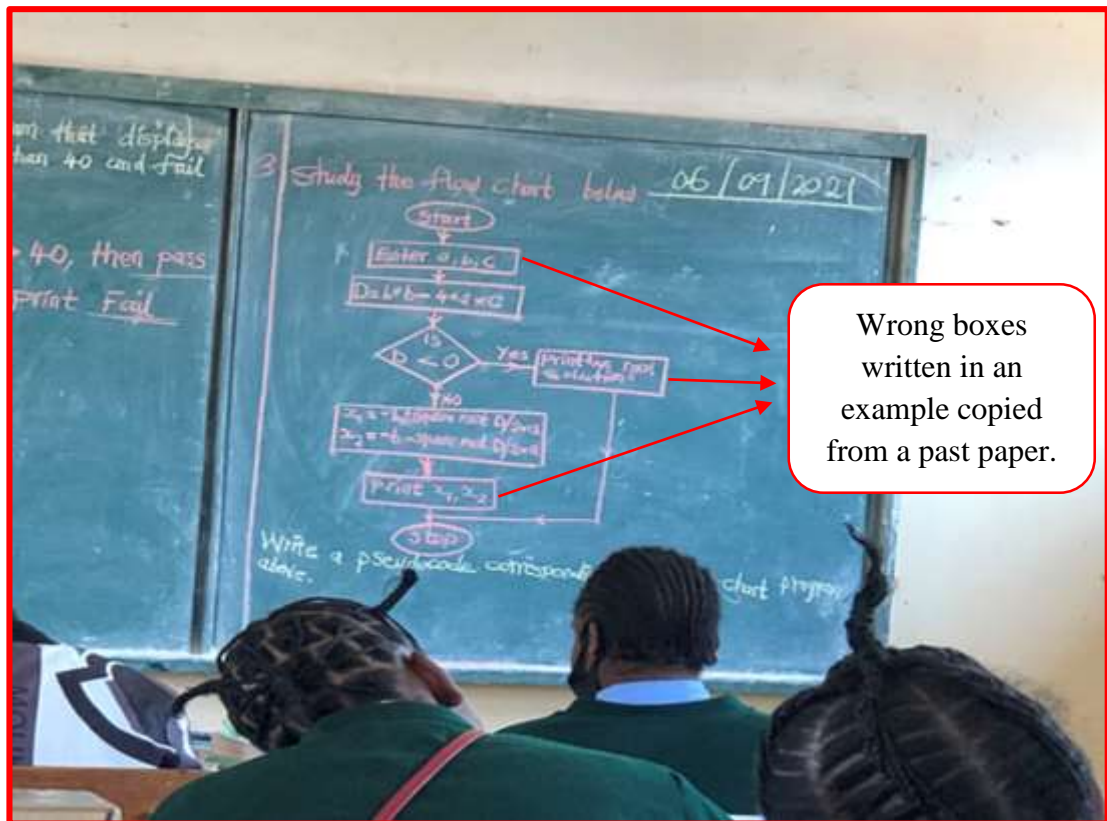


Figure 10: Showing a given example from a past paper written with an error by the teacher, Math specimen paper 2 (2016, p.6)

4.2.2 Specialised Content Knowledge (SCK)

For this domain the following themes emerged;

4.2.2.1 Teachers' understanding of a flowchart

Findings from the questionnaire and lessons observed showed that one out of the three teachers had little understanding of a flowchart, evidence is in Figures 11 and 12 below.

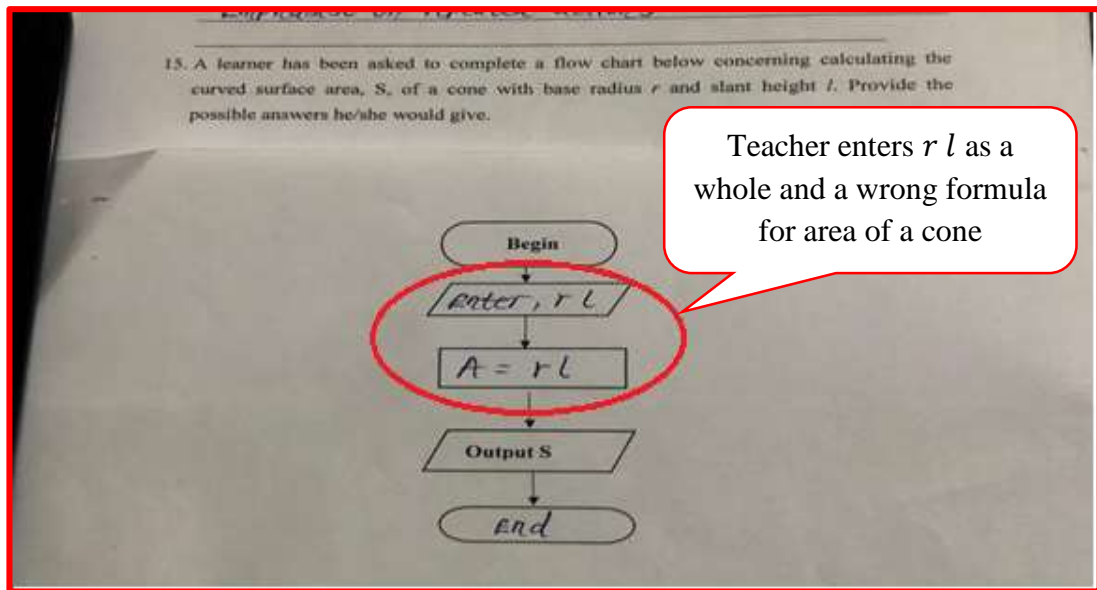


Figure 11: Questionnaire showing a partially correct solution by **T_Y B**

From the lesson observations the teacher would give an example and read it out to the learners. The teacher would then start answering the question by first saying this;

T_Y B, we know that in a flowchart, we are using boxes. Those boxes are the input, output, the process, the action box, the decision box all these. So first box is the start box...

Figure 12 below shows the teacher attempting the example while learners follow.

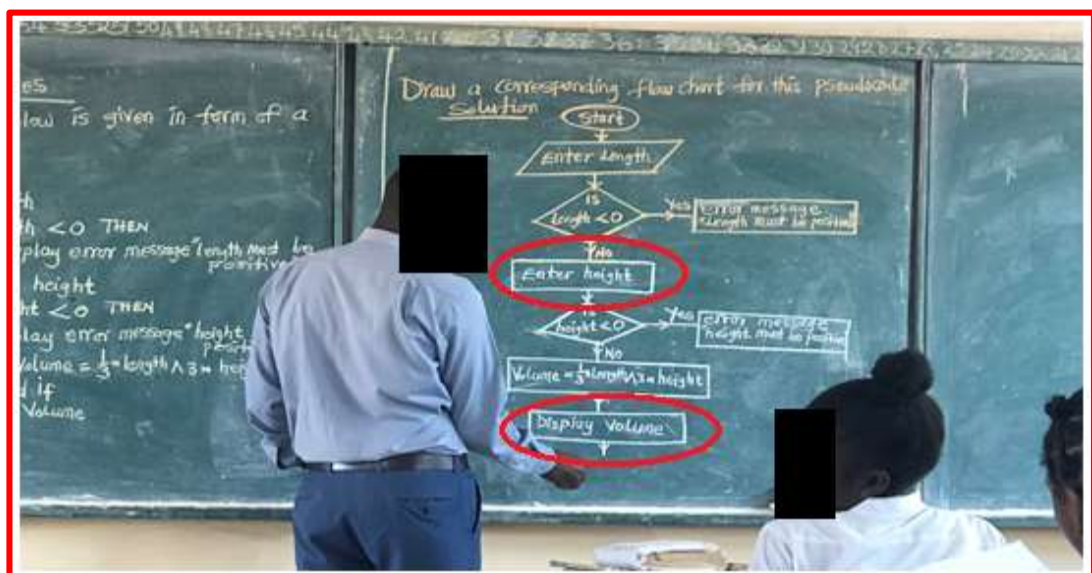


Figure 12: **T_Y B** answering the question wrongly by using the wrong boxes for the given instructions as also seen in Figure 8 (b)

The teacher went on to say;

the next statement says what? Enter height, we draw the corresponding box for the instruction. Next IF height is less than 0 then we display error message “height must be positive” ELSE volume is equal to(teacher writes the formula as in the pseudocode) END if, display volume then stop.

The other two teachers ($T_X A$ and $T_Z C$) however, were able to draw the correct flowchart when given a pseudocode in the lessons observed. The following are the snapshots for $T_X A$ and $T_Z C$ respectively;

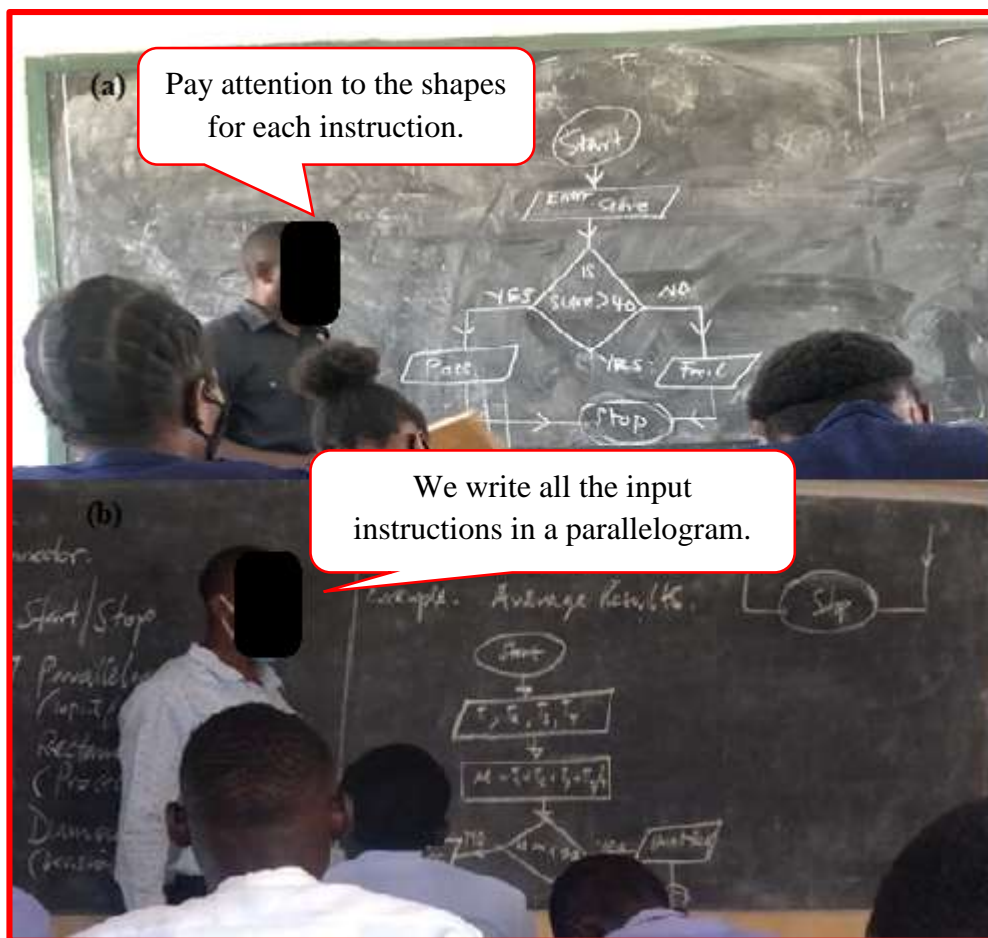


Figure 13: Correct solutions of a flowchart by $T_X A$ and $T_Z C$ in (a) and (b) respectively

4.2.2.2 Teachers' understanding of a pseudocode

From the questionnaire, a content question on pseudocode was given and all the three teachers answered differently as follows;

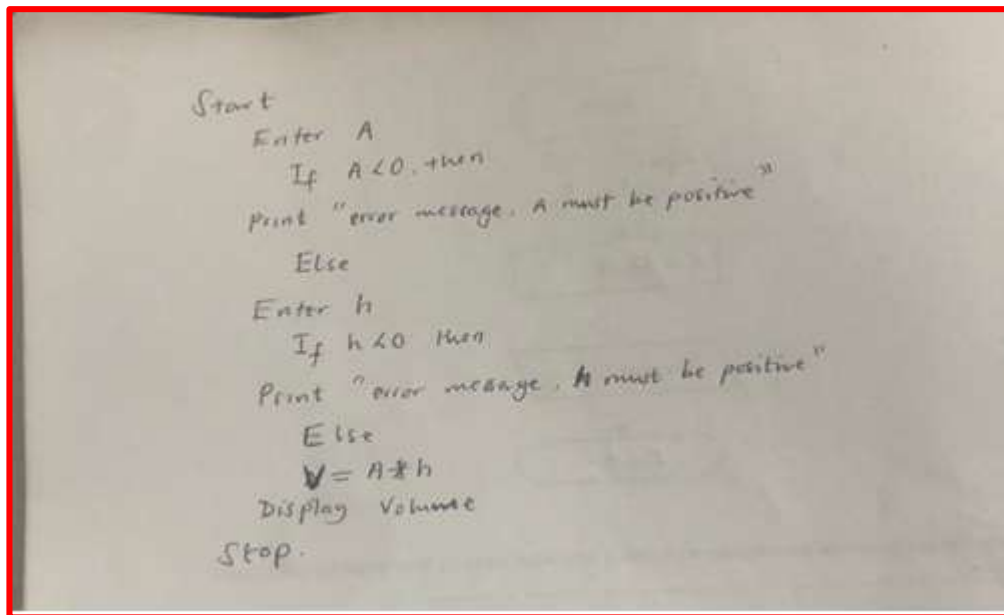


Figure 14: Solution for $T_X A$

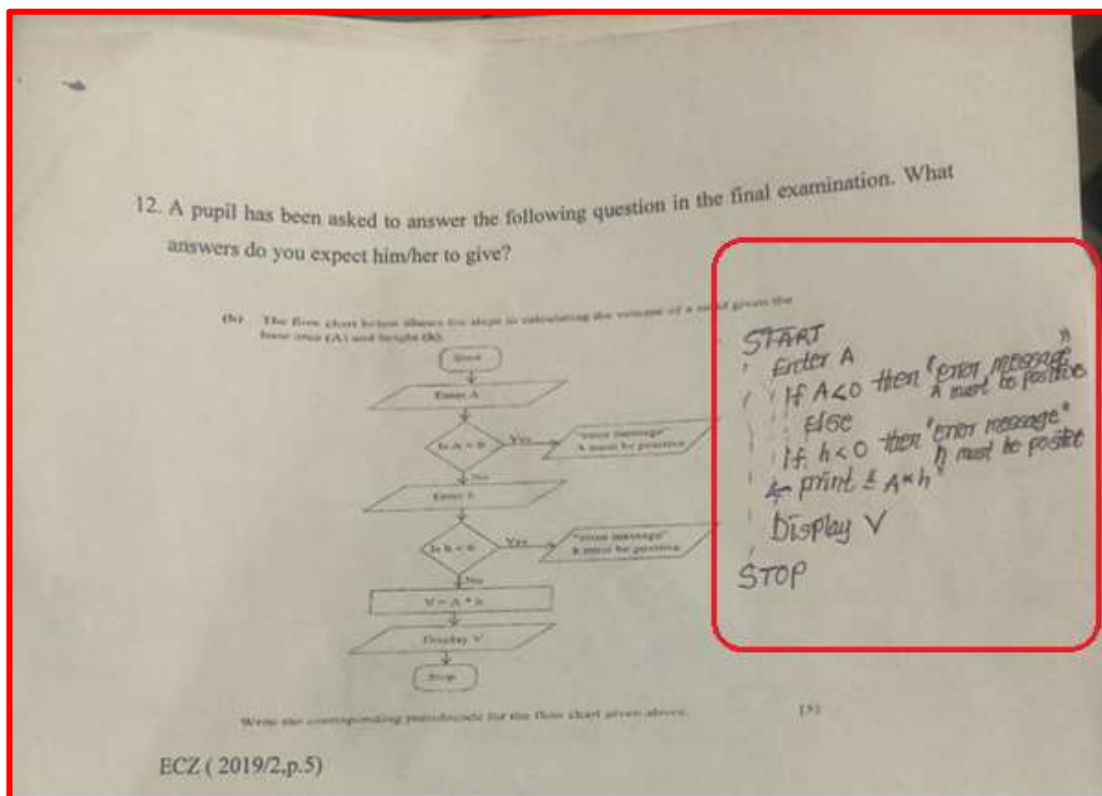


Figure 15: solution for $T_Y B$

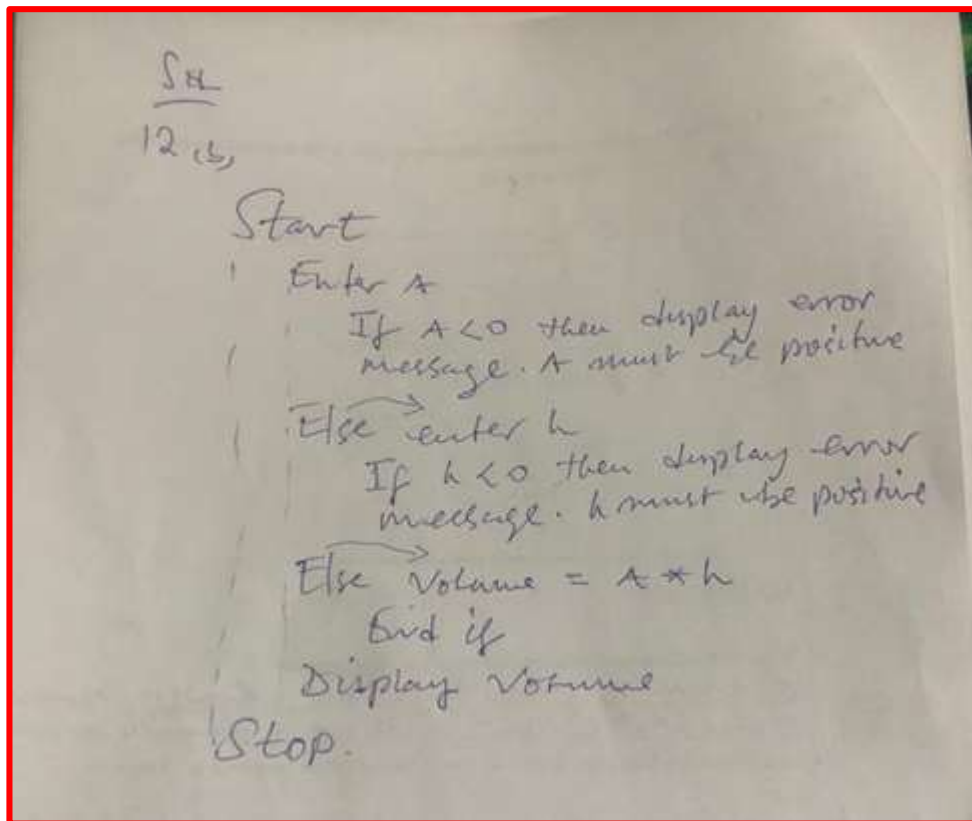


Figure 16: Solution for $T_Z C$

From the solutions above it is clear that *solution for $T_X A$* was correct while *solutions for $T_Y B$* and that of $T_Z C$ were partially correct with some errors.

Research findings from the lessons observed showed that $T_X A$ presented his pseudocode similar with how he answered in a questionnaire (see Figure 14) but with little mathematical explanation. $T_Y B$ explained the concept with examples, his presentation was a bit different from how he answered in a questionnaire (Figure 15). The following snapshot is evidence for $T_Y B$.

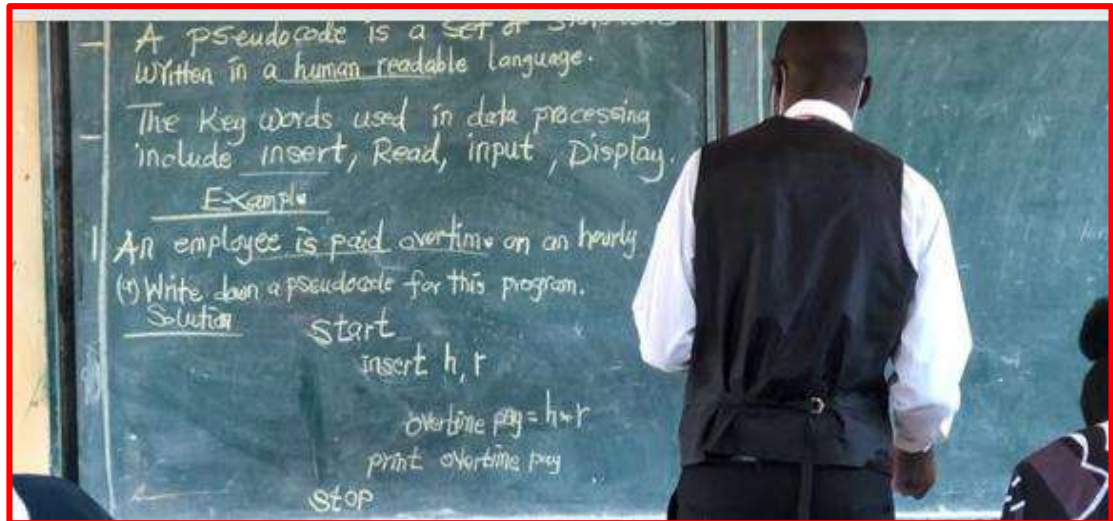


Figure 17: *T_Y B* writes and explain how to write a pseudocode

The following is the excerpt of the teacher (*T_Y B*) explaining how to write a pseudocode when answering an example shown in Figure 17 above:

The teacher first read the question;

An employee is paid overtime is on an hourly rate. So write down a pseudocode for this program.

Then the teacher continued to say;

***T_Y B** : Pseudocode like flowcharts, it will start just the way a flowchart begins. The first thing is start, then after you finish everything at the end you write stop! Sometimes you can even use 'begin' but you have to finish with 'end'. So solution....*

***Learners:** Sir is the solution going to fit on that space*

***T_Y B** : Yes, it will because this is not a diagram, this one is just simple statements...so It's not boxes where it would consume a lot of space.*

T_Z C, did not answer any questions on pseudocode apart from explaining to the learners some rules of writing a pseudocode. After the lesson, when he was asked why he did not answer any question on pseudocode, he had this to say;

*I run out of time trying to explain to them the steps on how to write a pseudocode. So, I gave work to do as a homework for them to go and practice then bring back I check.. **T_Z C***

4.2.2.3 Providing justification and responding to learners' why questions

From the lessons that were observed, all the three teachers were not giving enough justification for their explanations and the use of specific methods whenever a student asked. Teachers were not effective at helping learners with problems or questions. For example, when $T_X A$ was asked by the learner how he came up with the solution of an example on pseudocodes, he avoided the question and moved onto another concept. The following is the conversation between the teacher and the learners.

Learner 1; sir how did you come up with that? I don't understand the statements used....Learner 2; sir why are we not indenting the 'ELSE' too ?..... $T_X A$; let us look at another example you will understand...the problem is you don't pay attention when am explaining....Learner 1; mmmmmm but sir $T_X A$; ok I will give you as a homework...

Findings also showed that $T_Y B$ did not provide enough reasons as to why a process box (rectangle) was used when displaying an error message instead of the input/output box as seen in Figure 12 Section 4.2.2.1

4.2.2.4 Looking for common errors

Findings from the questionnaire and interviews showed that learners commonly make errors on identifying a loop, writing a pseudocode and wrong use of boxes and symbols. During the lesson observation findings showed that only one teacher out of the three paid attention to these errors by looking through the learners' work. The other two teachers $T_Y B$ and $T_Z C$ did not pay attention to the learners' errors but concentrated on teaching.

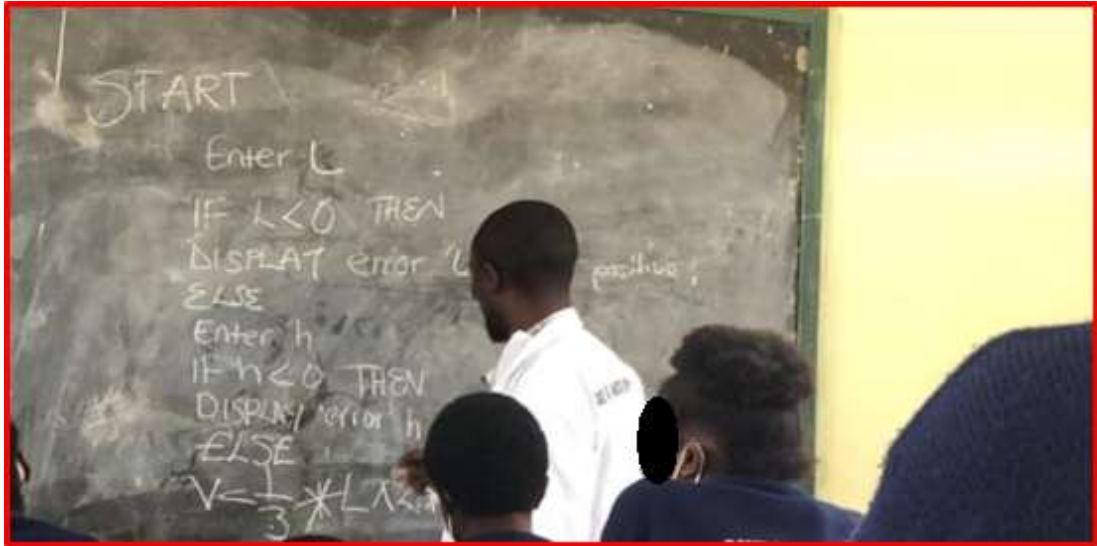


Figure 18: T_X A looking for common errors learners make



Figure 19: T_X A emphasizing on identifying a loop which is a common error

4.2.2.5 Linkage of computer to real life situations

Findings from the lesson observations showed that, two teachers out of the three teachers were able to link concepts to real life situations. When explaining a concept on looping (seen in Figure 19) or answering a question, T_X A and T_Y B would give an example from learners' experiences as an illustration. For example, T_X A gave the following illustration to explain the concept of 'Looping';

the concept of Looping is like when you fail to achieve something then you are given another chance” ...so if some of you here fails the final exams, you will be given a chance to rewrite under GCE unless you pass that’s when you can proceed to college

4.2.3 Knowledge of Content and Students (KCS)

Under this domain the researcher concentrated on the teachers’ attention to content and the learners. The following themes emerged;

4.2.3.1 Knowledge of learners’ difficulties

From all the three research instruments , it was clear that the teachers were familiar with learners’ difficulties. Teachers in the questionnaire listed down a number of difficulties that their learners have and where they make a lot of errors when learning the topic computer as mentioned in Section 4.2.2.4. Some of these difficulties were seen in the lessons observed.



Figure 20: Learner having difficulties in writing the pseudocode in **T_X A**’s class

From the interviews, teachers also revealed that they were aware of the difficulties that learners have in computer. Some teachers had this to say;

*From my experience so far, I know that most learners have difficulties in writing a pseudocode correctly I allow them to work on most of the questions first and together work on the mistakes if any” **T_X A** . “my learners have a challenge in understanding the concepts because of the nature of the topic, it is too abstract” **T_Y B**. “the main challenge is that pupils seem not to have strong base or*

background concerning computer, so pupils tend to just memorize things other than understanding. As a result pupils have a lot of difficulties with the whole topic at senior level. **T_Z C**

4.2.3.2 Type of work given

From the lessons observed, most of the work given by all the three teachers were interesting, however, too abstract and, not very challenging and not motivating. Teachers gave examples from textbooks and past papers. **T_X A** and **T_Z C** did not provide more examples that could take learners into deeper thinking. **T_Y B** provided more than one example but the examples were very simple for the learners as compared to the tasks given.

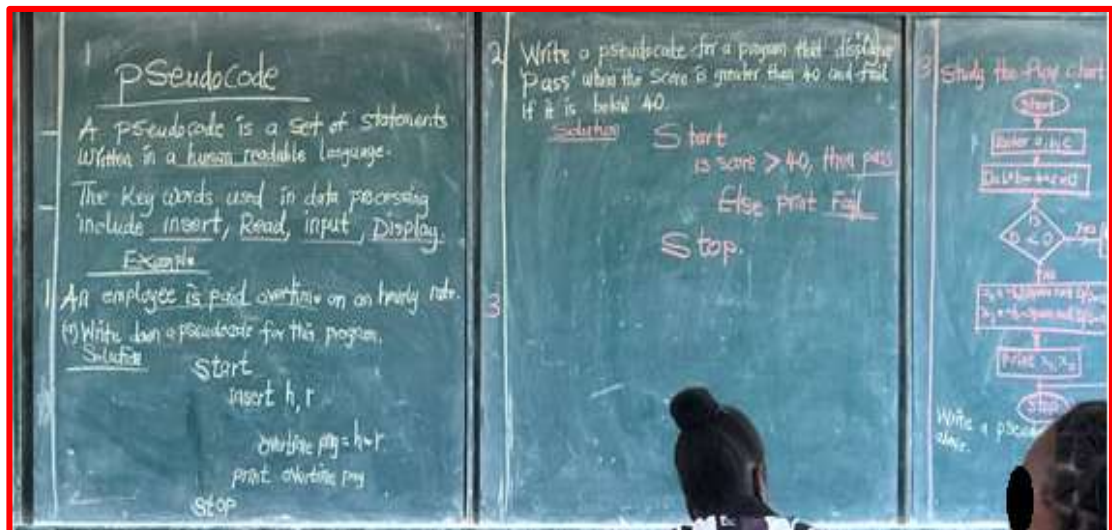


Figure 21: Showing examples given by **T_Y B**

4.2.3.3 Learners' participation (engagement)

It was observed that **T_X A** actively engaged learners in answering the questions. The teacher asked learners questions and most learners frequently responded to teacher prompts. Learners in **T_Z C**'s lessons were passively engaged, listened to or watched the teacher. Majority of Learners in **T_Y B**'s lessons appeared distracted or disengaged. This is evidenced in the following excerpts and snapshots;

Conversation between the learners and **T_X A**

Teacher asked learners how to write the pseudocode and calls them to attempt.

T_X A; *is this how it is supposed to be?*

Learners (almost everyone); *YES!*

Other learners(few); *NO SIR!*

T_X A; *why do you say no?*

Learner 1; *the term 'ELSE' is not supposed to be there... I mean it there should be a space left in front*

T_X A; *you mean 'indented'?*

Learner 1; *yes sir*

Learner 2; *it also says enter h, it should be re-enter h..... The teacher then allows learners to go and work on the task from home.*

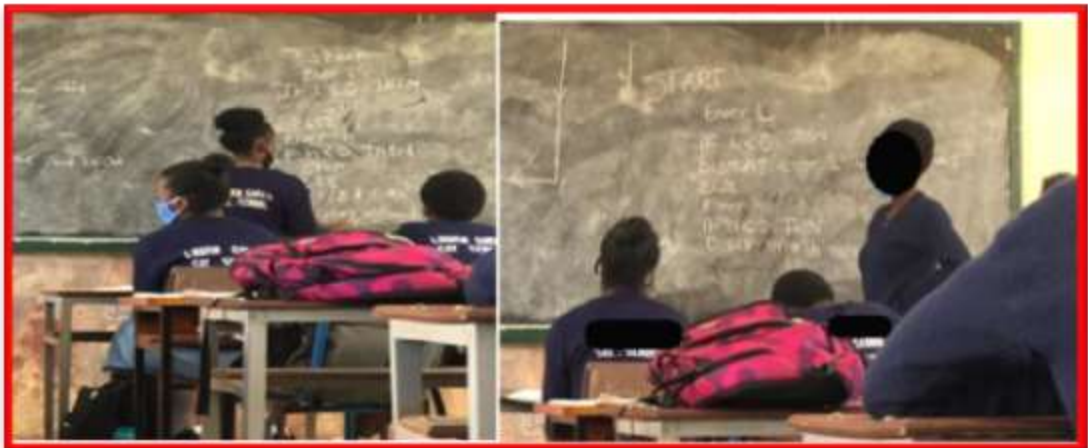


Figure 22: *Students in T_X A's class participating actively by responding to questions on the board*



Figure 23: Students appear less actively involved during the lesson as $T_z C$ explains the concept

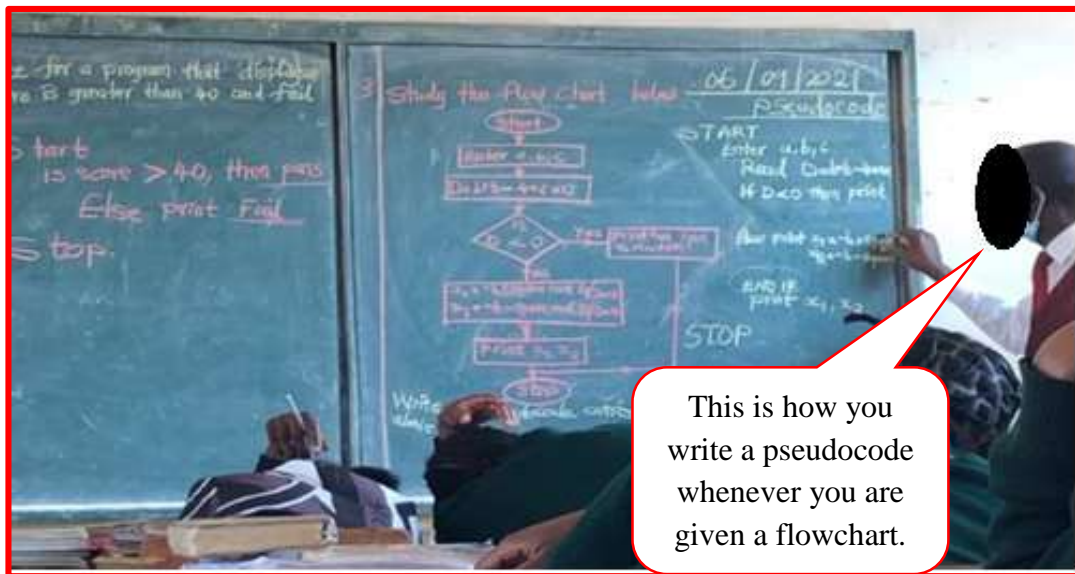


Figure 24: Showing some learners sleeping while $T_y B$ explains

4.2.4 Knowledge of content and teaching (KCT)

The following themes emerged from this domain;

4.2.4.1 Knowledge of teaching pseudocode

From the lessons observed each teacher showed different competencies in teaching the concept of a pseudocode. **T_X A** presented his work well with the help of the simplified notes (see Section 4.3.2.1) He read out the main points of how to write a pseudocode to the learners and assisted learners where they were behind. **T_Y B** explained the basics but emphasis was not made on challenging areas for the learners. Some concepts were not fully attended to on pseudocode like the concept of repeated actions like the other teacher did (see Section 4.2.2.4). **T_Z C** did not go in details in explaining the concept. In an interview, **T_Z C** revealed that he has little knowledge on how to go about a pseudocode when teaching. This is evidenced in the excerpt below;

*pseudocode is a challenge for me to teach because it is not standardized...the language used is not formal...I am not sure how to handle it, still studying on it. I even have a question mark on how the markers mark, whether they consider several types of answers that are close to each other or what? **T_Z C***

4.2.4.2 Knowledge of teaching flowcharts

Findings from the questionnaire and the lessons observed showed that, one teacher was not conversant in the teaching of flowcharts. In most cases **T_Y B** had challenges in using the correct boxes when drawing a flowchart (see section 4.2.1.2, Figure 8). The teacher was not consistent in the way he was teaching flowcharts. **T_Y B** failed to craft good questions to gauge the learners' comprehension. Learners were not given a little while to experiment with the flowchart (see Section 4.2.3.2, Figure 21).

4.2.4.3 Design and sequence of instructions

All the three teachers had their instruction designed specifically for computer. Some instructions were too abstract and more teacher centred than learner centred. The teachers in most cases did the talking and, in some cases, engaged learners when teaching the topic (see Section 4.2.3.3, Figure 23). The examples were sequenced in a

manner that learners were able to follow. Most of the content (work) given to the learners came from grade 9 and grade 10 textbooks just a few from the ECZ past papers (see Figure 10 and 21). $T_X A$ taught flowcharts and pseudocode side by side, $T_Y B$ taught flowcharts first then pseudocode and $T_Z C$ started with basics then application. The figure below shows the teacher explaining to the learners the basic steps needed when drawing a flowchart. The teacher first introduced the topic algorithms, then the two ways of presenting an algorithm.

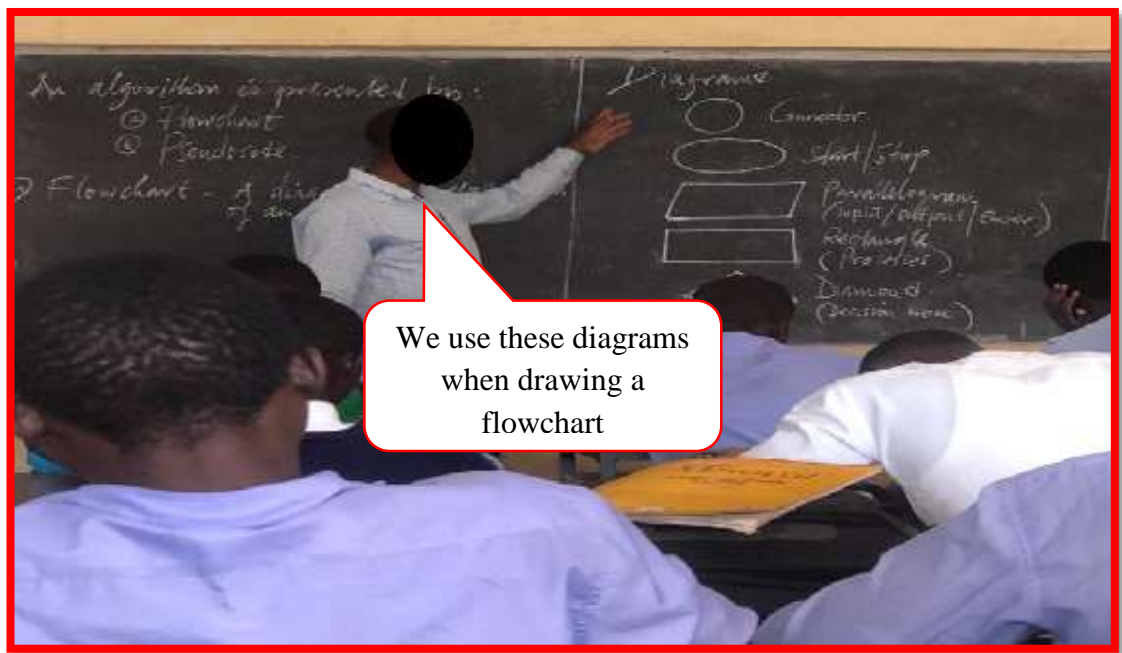


Figure 25: The teacher introducing the topic ‘Algorithms’

After the observations, each was asked why they taught the topic the way they did, the methods and design they used as mentioned above. It was revealed that the teachers understood the advantages and disadvantages of using those methods as evidenced in the excerpts below;

$T_X A$ said, *that method helps the learners understand the concept clearly*

$T_Y B$ said, *the method makes my teaching easier and learners are able to compare and differentiate*

T_Z C said, you know when pupils have a background, the chance of them understanding the concepts as the topic unfolds is high. That's why I teach like that

4.2.4.3 Remediating errors

From the lessons observed, two teachers were not very effective in remediating learners' errors. Some errors were not attended to immediately but pushed to the next lesson. **T_X A** was taking time to go through some learners' errors together with the whole class and come up with the correct solution as seen in Figure 9. In contrast, the other two teachers **T_Y B** and **T_Z C** did not pay attention to learners' errors, it was unclear how they were addressing the errors observed by the researcher (see Section 4.2.2.4).

4.2.5 Summary of the findings for research question 1

Table 5: Summary of the findings for research question 1

Domain	Indicators	Teacher <i>x</i>	<i>teacher y</i>	Teacher <i>z</i>
Common content knowledge (CCK)	- Definition of concepts in computer	√	√	√
	- Recognize inaccurate definition from textbooks	√	*	√
	- knowing when learners have answers wrong.	√	√	√
	- Correct use of terms and notations for computer when speaking and writing on the board.	√	*	√
Specialized content knowledge (SCK) & Mathematical challenge (MC)	- Sizing up the nature of the error	√	*	*
	-Provide mathematical explanations for common rules and procedures in computer	P	P	P
	-Recognizing and explaining conceptual differences and relationships	√	√	√
	-Explaining the understanding of concepts	√	*	*
	- Justifying rules and use of specific methods	*	*	*
	- Teacher crafting good questions	√	*	P

Key: √ means the teacher performed * means the teacher did not perform

	- Capacity to represent computer concepts in different forms	√	√	*
Knowledge of content and students (KCS) & Sensitivity to students (SS)	- Type of examples given (interesting and Motivating).	*	*	*
	-Familiarity with learners' errors	√	√	√
	- Ability to hear and interpret learners' emerging and incomplete thinking.	*	*	*
	- Teacher paying attention to learners' work, making sure all learners in the class focus and participate in the learning activity.	p	p	*
	- Interaction between specific mathematical understanding and familiarity with learners and their mathematical thinking.	*	*	*
Knowledge of content and teaching (KCT) & Management of learning (ML)	- design specific instruction for computer.	√	√	√
	- Remediating the learners' errors.	√	*	*
	- Instructional strategies when teaching a specific concept.	√	√	*

	- Sequencing of particular content for instruction	√	√	√
	- Teacher's ability in managing the class to help create positive atmosphere	√	√	√
	-Interaction between specific mathematical understanding and an understanding of pedagogical issues that affect student learning of computer.	*	*	*

P means partially done

4.3 Research question 2: What instructional strategies do teachers of mathematics use when teaching computer?

Research question two focused on the instructional strategies' teachers use when teaching computer. These strategies were simply the techniques teachers used to help learners become independent strategic learners in computer. In order to explore the instructional strategies, open-ended questionnaires were administered, lessons observed and semi-structured interviews were conducted. The strategies are presented according to the specific concept.

4.3.1 Flowcharts

4.3.1.1 Using basics and common rules

From the lesson observations, it was seen that teachers were using basic knowledge and common rules when answering questions on flowcharts and pseudocodes. For flowcharts, teachers were mainly using the shapes with their specific use as a guide for drawing a flowchart. Teachers were first reading the algorithm, identify the key terms used, pick the corresponding shapes and draw a flowchart according to the general rules.

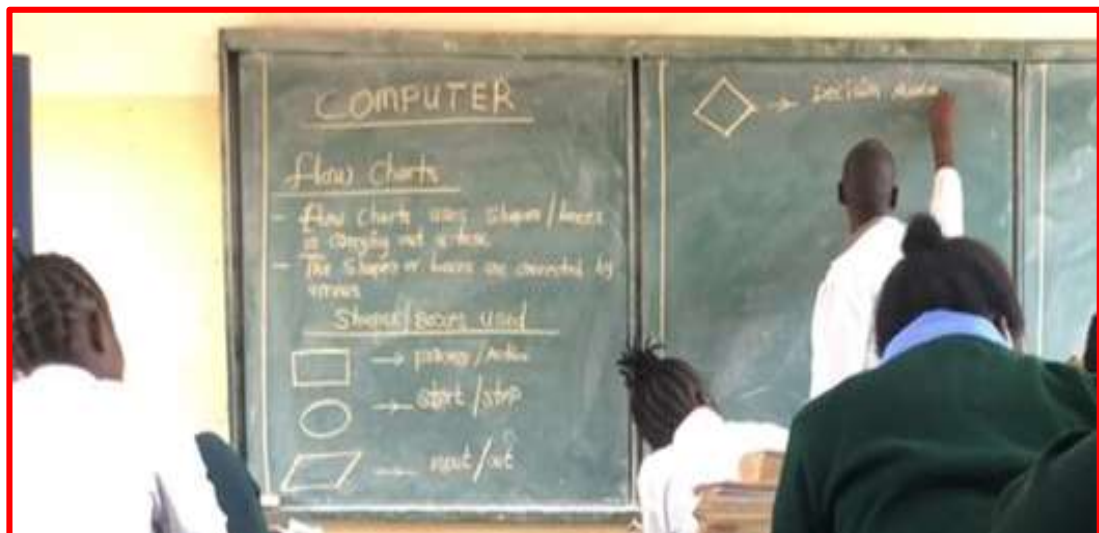


Figure 26: Showing T_Y B writing down the points and shapes for drawing a flowchart

Below is an extract of the teacher (**T_Y B**) explaining the rules of drawing a flowchart

*Flowcharts uses shapes or boxes in carrying out a task and we use arrows to connect these boxes. So, let us list these shapes before we look at an example... the first box is a rectangle which is a process or action box, next is the oval for start or stop...**T_Y B***

In an interview when teachers were asked on how they were teaching the concept of a flowchart , they had this to say;

T_Y B *“for the flowchart, I go straight in introducing the boxes and just emphasize that each statement should be in one box, no box should contain more than two statements”*

T_Z C *“I start with the basics (some simple rules).. learners should understand that a flowchart is a kind of pictorial reflection of an algorithm, then I write down the shapes used and how they are used. The rest is just to apply by drawing.”*

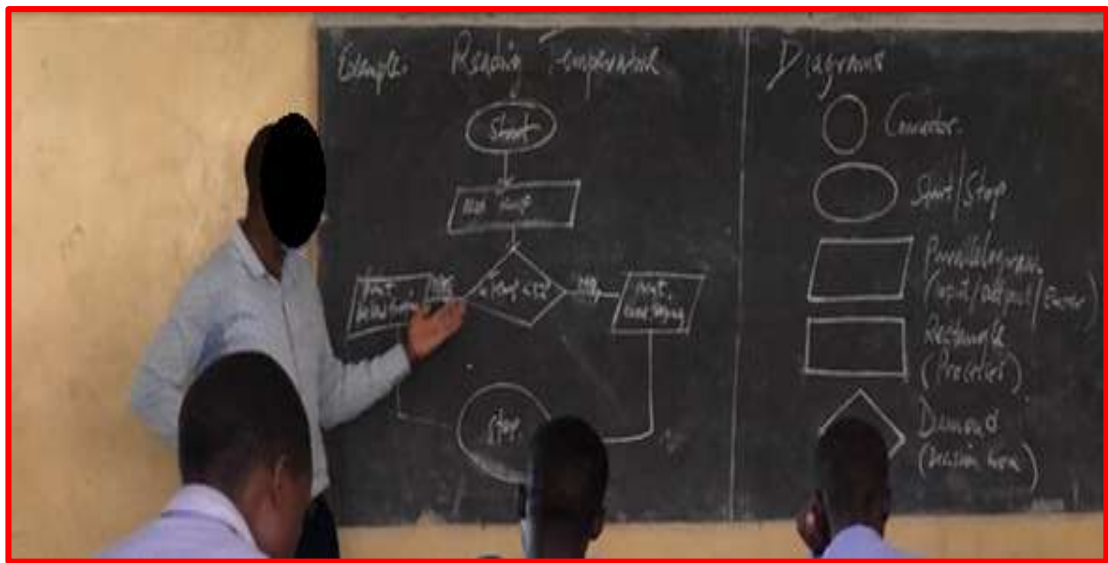


Figure 27: Showing **T_Z C** applying the rules of drawing a flowchart

The following is an extract of the teacher’s conversation as shown in figure 27;

let us look at an example of reading temperature, the first thing we do is start, so we draw the shape for start, secondly, we want to enter temperature so draw a box for entering which is a parallelogram...is temp less 12°, this is a question so we put in a decision box...

4.3.2 Pseudocode

4.3.2.1 Using common rules/steps

For pseudocodes, teachers ($T_X A$, $T_Y B$, & $T_Z C$) were also using the common rules/steps when teaching how to write a good pseudocode. The snapshots below are examples of the teacher giving out general rules of writing a pseudocode.



Figure 28: Showing the teacher ($T_X A$) reading out rules to learners

Below is an excerpt of what the teacher was saying followed by the snapshot of the learners' book with the given points on pseudocode:

Teacher reads out “*guidelines for designing a good pseudocode*”

The statements must be short, clear and readable...

The statements must not have more than one meaning...

Pseudocode lines should be clearly outlined and indented ...

A pseudocode shows clearly a 'start' and a 'stop'

The input, output and process statements should clearly start with the key words such as PRINT, READ, INPUT e.t.c

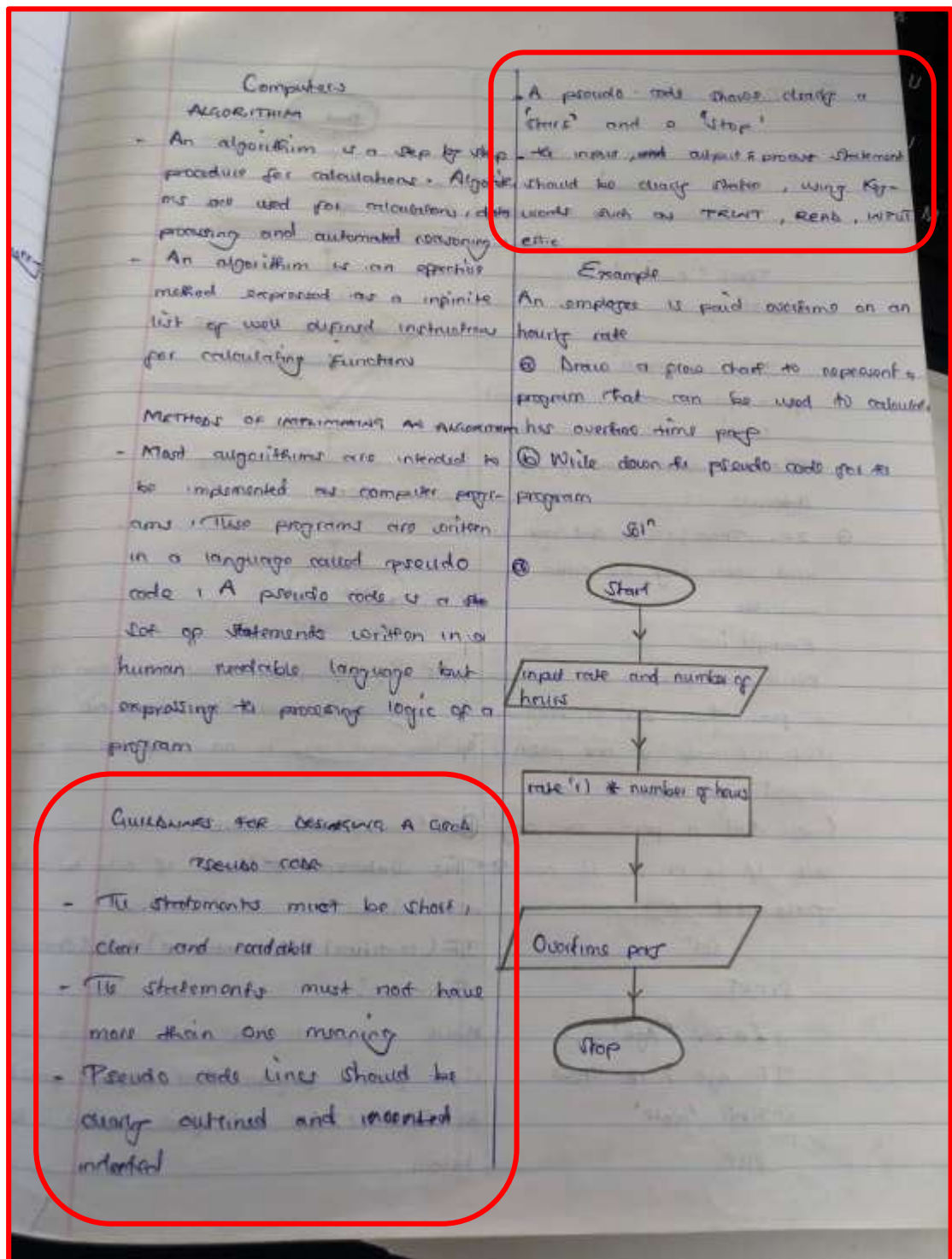


Figure 29: learner's book showing guidelines on how to write a pseudocode given by T_X A

Teachers in an interview said;

T_X A, "I just explain to them (learners) the **main points** like the **steps** on how a pseudocode should be written, that's all. ...most books are

not clear about how to go about a pseudocode and this is why most teachers shun away from teaching this topic”

T_Z C, “a pseudocode has no standard way of writing it so just some simple rules are needed to come up with a good pseudocode”.

4.3.3 Indenting

Lesson observations and interviews showed that two teachers were using two different strategies when explaining the concept of indenting in a pseudocode.

4.3.3.1 The principle of sequence and selection

After the lesson observations, teachers were asked few questions on the specific strategies they were using in teaching certain concepts like how to indent statements in a pseudocode correctly. One of the teachers said;

T_Z C , “there are few instructions that have been given regarding indenting in a pseudocode, for example, when a set of instructions are given on the same aspect, it means those set of instructions should start on the same column. I refer to that as ‘sequence’ keeping statements in a sequence, all in the same column”. “Other things also fall under what is called ‘selection’ some terms like IF.... THEN...ELSE, END IF should be used in the same column”.



Figure 30: T_Z C explaining how to indent in a pseudocode

From Figure 30 above the teacher was saying;

..there are a number of rules on pseudocode but let's talk about indenting. we indent to show the hierarchy So indent always indent the keys words like ENTER and END IF, statements in a sequence, statements that fall inside a loop..

4.3.3.2 The use of the ruler to draw two adjacent lines

Another teacher used the ruler as a way of guiding him on how statements in a pseudocode should be aligned. This is evidenced in the snapshot below;

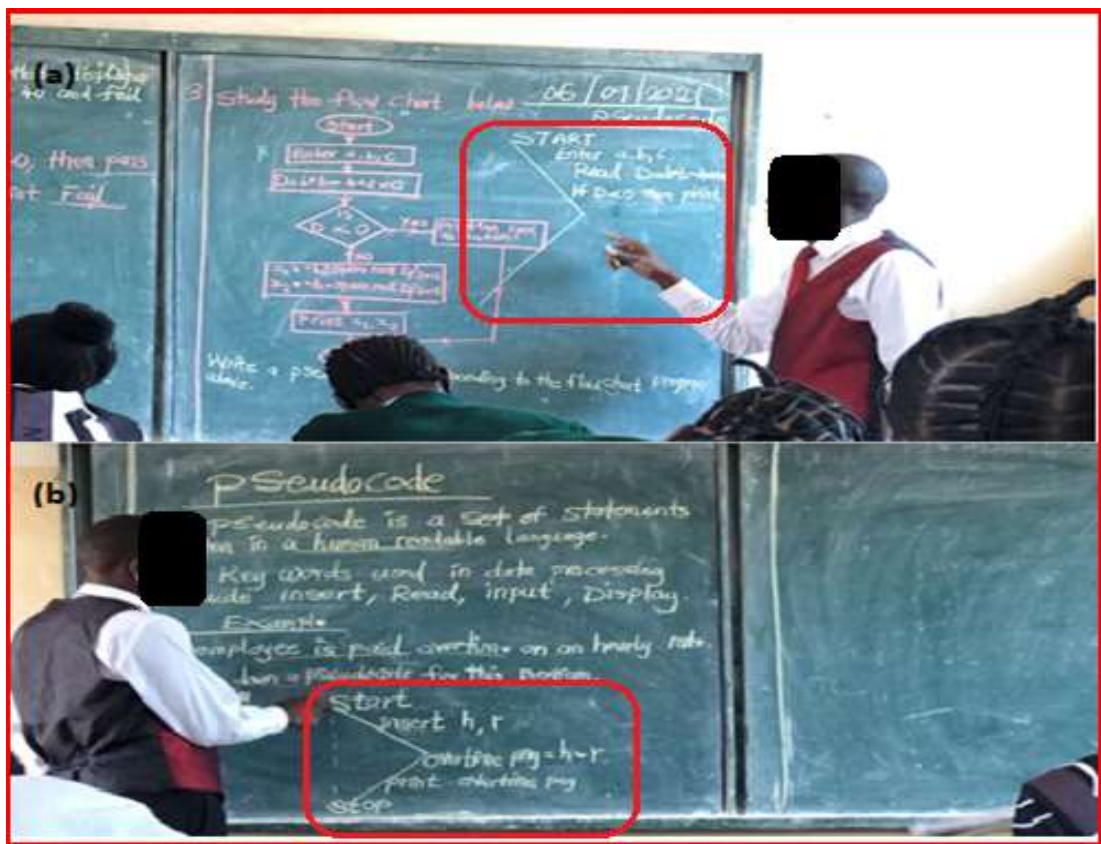


Figure 31: **T_Y B** demonstrating how to indent statements in a pseudocode

Below is an excerpt of what the teacher in Figure 31 was saying;

first draw two adjacent lines like this (teacher draws on the board), then start writing the given statements by following the two lines. You will see that it creates a triangle like shape

4.3.4 Sequence of instruction

The researcher also took note of the sequence of the instruction in looking for the instructional strategies, teachers of mathematics use when teaching computer. The three teachers sequenced their instruction in two different ways as also mentioned in Section 4.2.4.3 above.

4.3.4.1 Teaching flowchart and pseudocode side by side

Two teachers ($T_X A$ and $T_Z C$) taught flowcharts and pseudocodes side by side. An introduction was done of what algorithms are and then ways of implementing an algorithm. The two teachers gave examples on how to write a pseudocode when given a flowchart and vice versa. This is evidenced by the snapshot below;

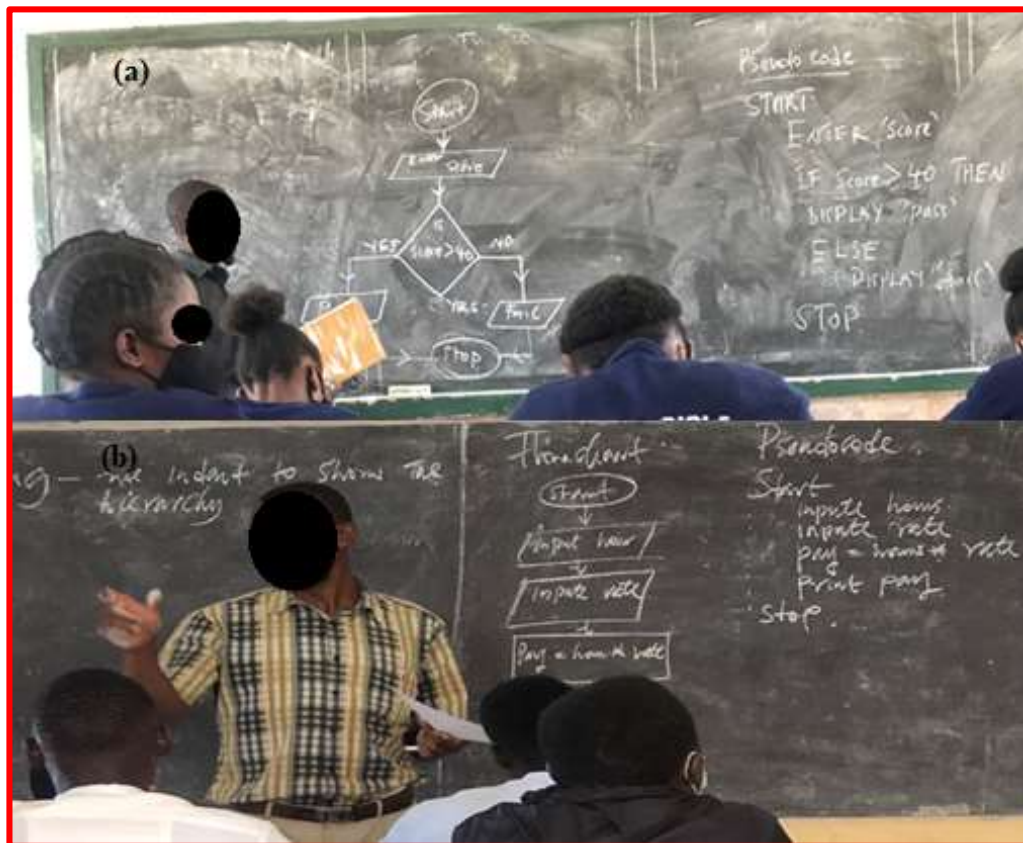


Figure 32: showing the teachers ($T_X A$ and $T_Z C$) teaching flowcharts and pseudocodes side by side.

The following are the excerpts of what the teachers were saying respectively;

$T_X A$, “For example, we are given this pseudocode and asked to write the corresponding flowchart. So we draw our flowchart by just copying the same

statements into the corresponding box like this..”(teacher draws the flowchart on the board).

T_Z C “an algorithm can be presented in two ways, it’s either in form of a flowchart or in form of a pseudocode...and in an exam they can only ask you to write one of these”.

4.3.4.2 Teaching flowchart then pseudocode and vice versa

Each sub topic was taught independently, the teacher discussed the flowcharts first, how to draw a flowchart by giving out a number of examples and an exercise. Secondly, discussed pseudocodes by answering different examples and concluding with an exercise. To conclude the whole topic, the teacher went through different past papers with the learners.

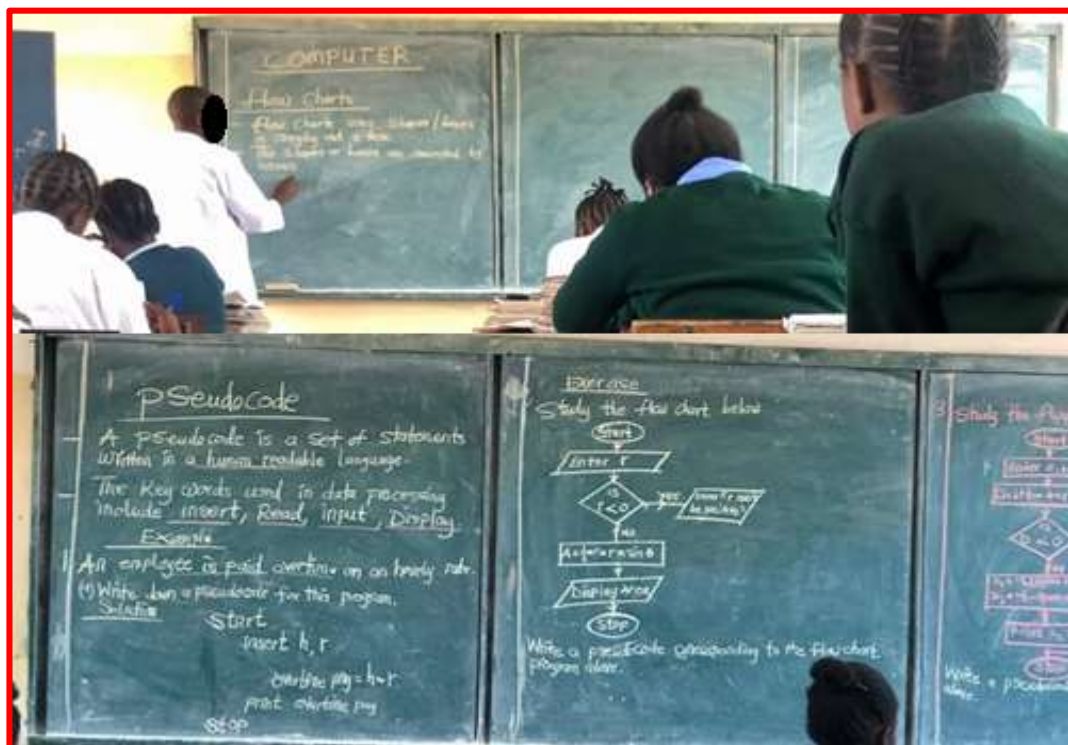


Figure 33: Showing the design of the instruction by **T_Y B**

The learners in the figure 33 above were expected to know how to draw a corresponding flowchart for a given pseudocode and how to write a pseudocode when given a flowchart.

4.3.5 Summary of the findings for research question 2

Table 6: Summary of the findings for research question 2

Instructional strategies	Activity
Using common rules/steps	Teachers were following the common rules and steps from textbooks when writing a pseudocode and drawing a flowchart
Indenting by sequence and selection	Following the way statements are sequenced when indenting a pseudocode
Indenting by two adjacent lines	Drawing two adjacent lines as a guide for how statements should be aligned in a pseudocode
Sequence of instruction	<ul style="list-style-type: none">- Teaching flowchart and pseudocode side by side- Teaching flowchart then pseudocode and vice versa

4.4 Research question 3: How do teachers' mathematical knowledge for teaching computer influence their instructional strategies?

The question was focused on establishing how the mathematical knowledge that teachers have for teaching computer (CCK, SCK, KCS and KCT) influence the way they teach. Four themes emerged from analysing responses in the questionnaire, the lessons observed and during the interviews.

4.4.1 Organisation

From the lesson observations, $T_X A$ was organized in the way he presented most of his work. The teacher prepared simplified notes for learners to easily understand the topic which is perceived to be too abstract. The examples and exercise were in line with the concepts taught and presented in a way a learner could follow. Attention was given to both the content and the teaching. In an interview when $T_X A$ was asked how he designed his instructions, he had this to say about his teaching;

generally, this topic is challenging especially that it is newly introduced in mathematics and few teachers of mathematics were trained. However, one just needs to understand the concepts. For me I concentrate on just two parts, flowchart and pseudocode. I teach them side by side, because of showing learners that a programme can be presented in different ways. I first emphasize the main points on how to write and draw a pseudocode and a flowchart by giving them simplified notes from the previous classes I taught. I also take time to go through the learners work then discuss the errors.

$T_Y B$ and $T_Z C$ however, were partially organized when it came to presentation of most of the examples. Teaching was mainly by book, and partially organized, the teachers were seen back and forth looking for what to give to /selecting what to give the learners right there in class as a result there was no coherence between the examples and exercises (see Section 4.2.3.2 and Section 4.3.4.2, Figure 33).

4.4.2 Time management

From the lesson observation, two teachers were observed to have issues with managing time. Teachers were seen going around the same point when explaining a specific concept, as a result running out of time for more class activities. Due to loss of time

some content were not taught as given in the syllabus. More time was spent on trying to address the mistakes. $T_Z C$ for instance, was not able to give any exercise or attend to all learners' queries, in almost all his lessons because of loss of time (see Section 4.2.2.2). There was no time given to learners for discussion and for looking for errors. Due to the calculation errors $T_Y B$ was making and the inconsistency in answering questions as seen in Figure 12 above, not much was covered in terms of content as expected. For those lessons where teachers were seen to know what they were doing like those with no mistakes or calculation errors, not much time was lost and were able to cover a lot in a short period of time.

4.4.3 Confidence

From the researcher's observation, one teacher out of the three teachers showed confidence in almost all the lessons. $T_X A$ was confident in teaching the topic. He was able to give clear mathematical explanations and justifications with no hesitation. He was diligent in whatever task at hand. $T_Y B$ however, was failing to justify some concepts on flowcharts confidently, in some cases he was not sure of what he was explaining. $T_Z C$ was also not sticking to his answers when it came to responding to the learners. They are cases where teacher would be challenged by the learner, (see Section 4.2.2.3) for evidence.

4.4.4 Consistence

It was observed that some teachers were not consistent with the teaching of some concepts. $T_Y B$ was not consistent with explaining how to draw a flowchart. There was misrepresentation of content for instance, the same shape would be used differently under the same question (see Section 4.2.1.2 Figure 8 (b)). The teacher was also not consistent in responding to learners questions. In some cases, justifications given to learners were contradicting the teacher's initial explanation of a particular concept as seen in Section 4.2.2.1, Figure 12.

4.4.5 Summary of the chapter

Research question 1: What mathematical knowledge for teaching computer do teachers have?	
Domain	Findings
CCK	<ul style="list-style-type: none"> • All teachers were able to give well and clearly defined concepts • One teacher out of the three was unable to give correct names for some symbols used in a flowchart • Two teachers were able to recognize errors from text books and know when learners have answers wrong
SCK	<ul style="list-style-type: none"> • One out of the three teachers had little understanding of a flowchart; the teacher had challenges answering the questions on the board • Two teachers were partially competent with pseudocodes • All the three teachers were not giving enough justification for their explanations and the use of specific methods whenever a student asks • Only one teacher out of the three paid attention to these errors by looking through the learners' work • Two teachers out of the three teachers were able to link concepts to real life situations
KCS	<ul style="list-style-type: none"> • All the teachers were familiar with learners' difficulties

	<ul style="list-style-type: none"> • Most of the work given by all the three teachers were not very motivating and not challenging enough for learners to think critically • One teacher actively engaged learners in discussion, while the two partially engaged learners
KCT	<ul style="list-style-type: none"> • Each teacher showed different competencies in teaching the concept of a pseudocode • The teachers taught the basics but emphasis was not made on challenging areas for the learners. Some concepts were not fully attended to • Teachers showed incompetence in teaching pseudocodes • One out of the three teachers were not conversant in the teaching of flowcharts. • All the three teachers had their instruction designed specifically for computer • Some teachers were not very effective in remediating learners' errors. Some errors were not attended to immediately

Research question 2: What instructional strategies do teachers of mathematics use when teaching computer?	
Sub-topic	Findings
	<ul style="list-style-type: none"> • Using common rules/steps

Pseudocodes	
Flowcharts	<ul style="list-style-type: none"> • Teaching using common rules/ steps from the book
Indenting	<ul style="list-style-type: none"> • By sequence and selection - following the way statements are sequenced when indenting a pseudocode • By two adjacent lines - drawing two adjacent lines as a guide for how statements should be aligned in a pseudocode
Sequence of instruction	<ul style="list-style-type: none"> • Teaching flowchart and pseudocode side by side • Teaching flowchart then pseudocode and vice versa

Research question 3: How do teachers' mathematical knowledge for teaching computer influence their instructional strategies?	
Ability	Findings
Organisation	<ul style="list-style-type: none"> • $T_X A$ was organized in the way he presented most of his work • $T_Y B$ and $T_Z C$ were partially organized when it came to presentation of most of the examples
Time management	<ul style="list-style-type: none"> • Two teachers were observed to have issues with managing time. • More time was spent on trying to address the mistakes • There was no time given to learners for discussion and for looking for errors
Confidence	<ul style="list-style-type: none"> • $T_Y B$ was failing to justify some concepts on flowcharts confidently • $T_X A$ was confident in teaching the topic. He was able to give clear mathematical explanations and justifications with no hesitation • $T_Z C$ was also not sticking to his answers when it came to responding to the learners
Consistence	<ul style="list-style-type: none"> • Some teachers were not consistent with the teaching of some concepts • One teacher was not consistent with explaining how to draw a flowchart • misrepresentation of content (seen in Figure 12)

CHAPTER 5

DISCUSSION OF FINDINGS

5.1 Overview

This chapter discusses and analyses the findings of the study as presented in Chapter 4. The discussion is under the headings drawn from the objectives and research questions of the research. Reference is also made to the literature reviewed and the theoretical framework. Further, a meta- analysis of these findings was also made.

5.2 Demographic characteristics of the teachers

Demographic information was collected regarding research participants and this was necessary for determining whether the individuals were a representative sample of the target population. It was observed that the three teachers ($T_X A$, $T_Y B$, $T_C Z$) have been teaching mathematics for 8, 15 and 26 years in that order and have been teaching the topic computer since it was introduced in 2016. This information was important for discussion in that teachers with varying degrees of experience might approach the same topic differently in terms of instructional practices and understanding of the topic. It also helped in understanding whether observed outcomes were influenced by the teachers' level of expertise.

5.3 What mathematical knowledge for teaching computer do teachers have?

This section discusses the mathematical knowledge that teachers of mathematics have when teaching computer with the help of Ball's et al (2008) four aspects of MKT. Three teachers at three different schools participated in the study. In order to determine this, the researcher used three instruments as mentioned in section 4.1 above.

5.3.1 Common content knowledge (CCK)

This subsection provides a discussion of teachers' competences when teaching computer under the theme CCK. CCK is one of the aspects of Mathematical knowledge for teaching. According to Ball et al (2008), this aspect informs such teaching tasks as knowing whether a student's answer is correct, the definition of a concept, and how to carry out a procedure.

5.3.1.1 Well defined concepts

Defining terms or concepts is very important in any lesson, a definition enable us to have a common understanding of a word or subject; they allow us to all be on the same page when discussing an issue thus, this act should be done properly. Algorithms are an important foundational concept in computer because it models a wide range of important phenomena. As such, any teacher of mathematics would need to know what algorithms are and give a clear definition. Along with definitional knowledge, mathematics teachers need to be able to give illustrations or multiple examples to show that they indeed know the meaning of what they are talking about. From the lessons it was observed that all three teachers were able to articulate a fairly accurate definition for an algorithm and other concepts in computer like a pseudocode and flowchart. This is seen from how the teachers were defining the concepts when introducing the lessons and during the teaching of the whole topic. Teachers' clear definitions and illustrations suggest that they may have the common knowledge needed for teaching computer. This kind of competence is one of the attributes of CCK. According to Steele et al (2013), CCK is certainly prerequisite to being able to teach mathematics thus, having such knowledge is important even when teaching computer.

5.3.1.2 Use of terms and symbols

According to Ball et al (2009), common content knowledge is the knowledge teachers need in order to be able to do the work that they are assigning their learners. It can be therefore seen that; this kind of knowledge is important and without this knowledge the whole instruction will be affected. The findings showed that two teachers out of the three were able to use the terms and symbols correctly when explaining and writing on the board. These teachers wrote terms commonly used in computer the way they are supposed to be written and drew shapes correctly with the right function. However, one teacher partially knew how to use some terms and symbols. Wrong use of terms and symbols when writing is a sign of lacking some basic knowledge on the topic. As a teacher of mathematics this type of knowledge is also mandatory to have when teaching computer for it is vital to the whole instruction. It is difficult for a teacher who has problems with naming some symbols to use them correctly when it comes to application. It is also difficult on the part of the learners to know the correct thing if the teachers are not able to do the work that they are assigning their learners, which is

failing to use the symbols correctly. In an interview, when the teacher was asked about the symbols for drawing a flowchart, he said a parallelogram is used for entering data only. However, this is contrary to Charntaweekhun and Wangsiripitak (2006). A parallelogram can also be used for displaying or output data (see Section 2.4). This suggests that, the teacher had little common content knowledge on this area

5.3.1.3 Error recognition

Another finding under common content knowledge was error recognition. Ball et al (2009) alluded that CCK includes knowing when students have answers wrong and recognizing when the textbook gives an inaccurate definition. Some teachers were able to know when learners made mistakes in their books, on the board and when responding. For example, the teacher after going around the class and checking learners' books, he was able to recognize and note down errors that learners were making (see Figure 9). From the figure, the teacher observed that most learners were using a wrong box for displaying 'PASS' instead of using a parallelogram known for input and output statements. Learners were also using a rectangle which is meant for process or in short meant for a formula in a case of mathematics. This ability of the teacher recognizing when there is an error is in line with the attributes of CCK (Ball et al, 2009). In addition, Shulman's (1987) definition of content knowledge (CK), implies that the teacher had Knowledge of the actual subject matter to be learned or taught. As it is stated in the literature, this CCK is the mathematical knowledge and skills which even a nonteacher should have. The importance of this knowledge therefore in teaching computer, cannot be overemphasized.

One teacher (*T_Y B*) however, out of the three as presented in the previous chapter was unable to recognize whether a past paper had used wrong boxes or not. The teacher gave an example with errors and he did not see or recognize the situation as an error. It is important for a teacher of mathematics to be able to spot that the box being used for a specific instruction is incorrect. However, a teacher who only see that this is not a correct answer is not well equipped to help learners learn to get it right. This would suggest that the teacher's CCK on this area of the topic was not sufficient.

5.3.2 Specialized Content Knowledge (SCK)

Under this aspect the teachers were expected to show the mathematical knowledge and skills that are beyond the pupils' mode of thinking. Provide mathematical explanations for common rules and procedures in computer, and Justify rules and use of specific methods. SCK is another aspect for MKT. Steele (2013) emphasized the importance of specialized content knowledge (SCK) in teachers' abilities to plan, teach, and reflect on practice. This is the mathematical knowledge that is beyond that expected of any well-educated adult.

5.3.2.1 Teachers' understanding of a flowchart

It was observed from the questionnaire and lessons that one out of the three teachers was making a number of mistakes when answering questions on flowcharts (see Section 4.2.2.1 above). A content question was given in a questionnaire where teachers were asked to give possible solutions by completing the flowchart of finding the area of the cone. Teachers were expected to enter the required variables r and l in the input box as '*enter r, l or r, l*' instead the teacher entered rl which implies one variable. The teacher was also expected to enter the formula for the area of a cone as $A = \pi rl$ instead the teacher entered $A = rl$. This suggests that the teacher does not fully understand the concept of a flowchart and the rules attached to it. This practice is not in line with Shulman (1987) who argued that, teachers need to know beyond what they are required to teach. In this case the teacher did not seem to know or remember the correct formula of a cone which every teacher of mathematics should know. They needed to have vast content knowledge (CK) of the topics which they teach. From the lesson observations, the teacher gave a partially correct solution to the questions given as an example and he consistently used wrong boxes for input and output boxes. Overall, this practice could mean two things either the teacher did not understand the content under discussion or he did not fully know the meaning or the use of some boxes/shapes used in a flowchart. Not able to do all these suggests that the teacher has little SCK. SCK is another important aspect that teachers especially teachers of mathematics need to be able to teach effectively and efficiently. Like CCK, SCK plays an important role in the teaching and learning of computer. Teachers therefore, should have specialised content knowledge for teaching the topic, with emphasis on the areas that are key concepts in understanding flowcharts.

The other two teachers however, were able to answer questions on flowcharts correctly. The teachers seemed to understand the key concepts of a flowchart well, at least they were able to draw correct flowcharts accordingly. Although not many examples were given but from the few that teachers discussed with the learners, it can be said that the teachers were competent on this area of the topic. Ball et al (2009) argued that, this is the ideal knowledge and skills which a teacher of mathematics should possess. This was discovered after numerous questions were asked about the type of mathematical knowledge the teacher required to teach a specific topic. This means that teachers of mathematics do not just need CCK but also SCK which is a form of knowing mathematics not needed by those who do not teach.

In a theoretical review of specialized content knowledge by Flores et al (2013), SCK is considered as content knowledge that is beyond CCK. The authors looked at Ball's et al (2008) examples to illustrate SCK and said that the mathematical knowledge involved in the analysis of procedures leading to the detection of these errors is identified as SCK. Ball et al (2008) argued that, recognizing a wrong answer is CCK whereas identifying the nature of an error especially an unfamiliar error requires SCK. It can therefore, be said that the teachers' practice was in line with what the above authors alluded to. The teachers did not just know the definitions but they were able to provide and evaluate mathematical explanations of how errors occur in addition to recognizing and analyzing them.

5.3.2.2 Teachers' understanding of a pseudocode

Findings from the questionnaires showed that two teachers made some mistakes in their solutions. The first teacher (see Figure 15) left out some terms like 'Enter h ' that was in a flowchart when writing a corresponding pseudocode. Pseudocodes can be written differently but there are general rules for writing a good and correct one. According to Brousseau (1997), pseudocode is a technique used to describe the distinct steps of an algorithm in a manner that is easy to understand for anyone with basic programming knowledge. Therefore, being a teacher of mathematics with knowledge on pseudocodes, such a mistake should occur. Further, it is emphasized that pseudocodes must provide a full description of the algorithm's logic. In a case of the first teacher, he did not give a full description of what the algorithm was about by

missing out some information as given in the flowchart. This may lead to misrepresentation of information to the learners.

From the lesson observations all the three teachers answered questions on pseudocodes differently. This however is not a problem with writing pseudocodes. Pseudocodes have different ways of representing the same thing but emphasis is on the clarity and not style. Teachers therefore, need to have this specialized knowledge on pseudocodes and also make sure that they do not lose the learners in either explaining or writing on the board.

5.3.2.3 Providing justification and responding to learners' why questions

From the lessons that were observed, all the three teachers were not giving enough justification for their explanations and the use of specific methods whenever a student asked. Not able to provide justification or explanation or shunning away from learners' questions could be an indication that the teacher did not have enough knowledge or understanding on some areas of the topic. As a result, learners will be left with question marks that may affect them in the near future. For example, **T_V B** did not provide enough reasons for using a process box when displaying an error message instead of the input/output box. This practice by the teacher could result in a lot of confusion to the learners. Knowing the names and meaning of the shapes when writing a flow chat is the basic knowledge that every teacher should have, however, knowing how to use the shapes correctly is specialized content knowledge that a teacher of mathematics needs to have. Many studies have demonstrated how this type of knowledge is important to the teaching and learning of mathematics. According to Ball et al (2008) SCK is mathematical knowledge that is unique to teaching, it is beyond that expected of any well-educated adult. Shulman (1986, p.9) also argued that, "the teacher need not only understand *that* something is so; they must further understand *why* it is so". Therefore, failing to provide justification may imply that the teacher is not specialized in that area.

5.3.2.4 Looking for common errors

Looking for common errors is another indicator of SCK. It is important for a teacher to pay attention to the common errors that learners make on a particular topic. First the

teacher needs to be aware of those errors and secondly look for them in learners' working. It was observed that learners commonly make errors on identifying a loop, writing a pseudocode and wrong use of boxes and symbols. However, only one teacher out of the three paid attention to those errors by looking through the learners' work and be able to analyze the nature of errors while the other teachers concentrated only on teaching. For example, one common error when drawing a flowchart is wrong use of boxes and symbols, a teacher must be able to spot that the box/symbol used is wrong. This does not require any special knowledge to do. Anyone who knows how to use the boxes in a flowchart can readily see this. However, teaching involves more than identifying an incorrect answer. The teacher must be able to see and size up a typical incorrect answer, analyze how the error occurred and why it occurred. This is in line with the article by Nalube (2011) who argues that, it is important to know the source of the error before making any decision about remediation. Otherwise, if the source of the error is unknown, it was likely that the error would be corrected. Ball et al (2005; 2008) argued that, skillful teaching or effective teaching requires analyzing the source of the error.

5.3.2.5 Linkage of computer to real life situations

Two teachers out of the three teachers were able to link concepts to real life situations. When explaining a certain concept or answering a question, $T_X A$ and $T_Y B$ would give an example from learners' experiences as an illustration (see Section 4.2.2.5). As reviewed in the above literature, the importance of computer in mathematics cannot be overemphasized. It is argued that the concepts of pseudocodes and flowcharts provide a framework for the math process, giving learners a step-by-step approach to tackling the problem. Algorithms are also used in many branches of science and everyday life (Morley, 1981). It is therefore important for teachers of mathematics to refer to real-life situations in their teaching, this may help learners to connect what is being taught in computer and see its relevance to society.

5.3.3 Knowledge for content and students (KCS)

KCS is an important component of PCK. A framework of mathematics knowledge for teaching developed by Hill, Ball and Schilling (2008). Under this domain the

researcher concentrated on the teachers' attention to content and the learners. The following themes emerged;

5.3.3.1 Knowledge of learners' difficulties

From the interviews, it was clear that all the teachers were familiar with learners' difficulties. In the questionnaire teachers listed down a number of difficulties that their learners had and where they made a lot of errors when learning the topic computer as mentioned in Section 4.2.2.4. Some of these difficulties were seen in the lessons observed. Familiarity with learners' difficulties and deciding which of the several difficulties learners are mostly likely to make are indicators of knowledge of content and students (KCS). KCS enables teachers to anticipate, identify and resolve learners' misconceptions about mathematics. In an interview with some of the teachers, one teacher revealed that predicting his learners' errors was something that he did often because it helped him to plan for the instruction and be organised when teaching. This showed how important it is for a teacher to be familiar with the learner's difficulties. In line with the mathematical knowledge for teaching, it can be said that there was interaction between the content and the learners by the three teachers.

5.3.3.2 Type of work given

From the lessons observed, findings showed that most of the work given by all the three (3) teachers were not very motivating and not challenging enough for learners to think critically. Some examples were interesting but too abstract for some learners to understand. Computer is one of the abstract topics in mathematics and because of its nature most learners have difficulties in understanding the concepts especially if the teacher has not simplified the notes. As it was revealed by one of the teachers in Section 4.2.3.1 that the learners have a challenge with understanding the concepts because the topic is too abstract, teachers should therefore, be able to help learners understand concepts by giving work that is simplified, tangible but challenging too. Without providing learners with a variety of challenging tasks, learners often approach the topic with less attention and tend to just memorize things for the sake of the final examination other than understanding (Gardner,1987). Therefore, teachers should be more creative when it comes to choosing the type of work, craft or choose good examples that challenges learners to think critically and motivates them to study hard.

What this means in terms of MKT is that teachers need to have knowledge for content as well as for students (KCS), a type of pedagogical content knowledge that combines knowing about students and knowing about mathematics. PCK enables teachers to ease the learning for learners through presenting learning in interesting, motivating and even entertaining ways (Jaworski,1994; Shulman ,1987).

5.3.3.3 Learners' participation (engagement)

Learners' participation is here defined as learners being active and engaged in the classroom. It was observed that only one teacher actively engaged learners in the learning process. The teacher was giving learners chance to explain their answers and allowing them to solve on the board (see Figure 22). The teacher asked learners questions and most participated in discussions, asked questions, and learners frequently responded to teacher prompts. This is a good classroom practice as it helps the teacher to understand the learner's strengths and weaknesses thereby coming up with appropriate remediation to the errors noted. Allowing learners to participate in class also helps learners themselves to learn from each other, increasing comprehension through cooperation and improves critical thinking. Moreover, this shows that the teacher was sensitive to learners as well as showing knowledge of content and learners (Jaworski, 1994).

However, from the other two classes learners were seen not actively engaged in the learning process. Relaxed postures, slouching, or disengaged body language was observed which may suggest boredom or lack of interest (see Figures 23 and 24). The teachers were not paying attention to all the learners and allowing them to attempt some questions rather they concentrated on just explaining the concepts in a manner that seemed boring to the learners. As earlier discussed, computer is too abstract for a teacher to just be talking throughout the lesson minus letting learners take part. Not doing that, may suggest that the two teachers did not have the appropriate knowledge which is knowledge for content and students. The two teachers may have shown having knowledge of learners' difficulties but it was also important for them to be equipped with the knowledge of how to engage with learners or make the lesson more interactive. Research has shown that a good balance between Sensitivity to Students (SS) and Mathematical Challenge (MC) is needed for effective teaching; a lot of MC

but little SS can result in learners feeling stressed or unable to succeed (Potari & Jaworski, 2002). It can therefore be argued that, teachers should pay attention to learners as much as they do to the content and that is what KCS emphasizes (Ball & Bass, 2009). The goal of education can be brought down to one mission: foster learning and growth in learners in order to prepare them to lead productive and meaningful lives. This can only be achieved if learners are actively engaged.

5.3.4 Knowledge of content and teaching (KCT)

Related to KCS domain within PCK is knowledge of content and teaching (KCT), this is knowledge that combines knowing about teaching and knowing about mathematics. Ball et al (2008) emphasized that many of the mathematical tasks of teaching require mathematical knowledge that interacts with the design of instruction. The following themes emerged from this domain;

5.3.4.1 Knowledge of teaching pseudocode

From the lessons observed each teacher showed different competencies in teaching the concept of a pseudocode. **T_X A** presented his work well with the help of the simplified notes. He was able to discuss the main points in writing a pseudocode with the learners and assisted learners where they were behind. This was good as the teacher was not just able to show that he understands pseudocodes but was able to explain the concepts to learners in a simplified manner. This finding is line with Ball et al (2008) who argued that apart from interpreting student error teaching also involves knowing rationales for procedures, meanings for terms, and explanations for concepts. For example, teachers need to know effective ways of representing a pseudocode when teaching computer. It is one thing knowing the content but teaching it effectively so that learners understand is a different thing. Therefore, the point is not about what teachers need to teach, but about what they themselves need to know and be able to do in order to carry out any responsible form of teaching. In addition, Hill and Ball (2009, p.68) stated that “Good teachers know both content and how to “get it across” to their students”. The findings prove that understanding of content matters to teaching.

Although **T_Y B** was able to explain the basics emphasis was not made on challenging areas for the learners. Some concepts were not fully attended to on pseudocode like the concept of repeated actions. This concept requires the teacher to understand it fully

before teaching, however, this was not the case. The teacher should have instead paid more attention to this concept for effective and efficient teaching of computer thus enhanced learner learning of computer. From the interviews (see Section 4.2.4.1) *T_Z C* revealed that teaching pseudocodes has been a challenge since computer was introduced. However, the reasons the teacher gave could imply that he needed more knowledge on pseudocodes by researching from different teaching and learning materials for him to teach effectively. Teaching is about helping others learn to know and do. Therefore, teaching pseudocodes requires the teacher to be well equipped with knowledge for teaching it and help learners learn.

5.3.4.2 Knowledge of teaching flowcharts

Findings from the questionnaire and the lessons observed showed that, one out of the three teachers, was not conversant in the teaching of flowcharts. In most cases the teacher had challenges in using the correct boxes when drawing a flowchart and was not consistent in the way he was teaching the whole concept of flowcharts. The teacher also failed to craft good questions to gauge the learners' comprehension and learners were not given a little while to experiment with the flowchart. According to *Educating our Future* (MoE, 1996) it is explained that the essential competencies expected in every teacher are to master the subject matter to be taught and a skill in communicating that subject matter to the learners. However, the teacher seemed to have insufficient knowledge on flowcharts thus not able to teach this area of the topic effectively and efficiently.

The findings are also closely related to that of Ma's (1999) who highlighted the implicit relationship between mathematics knowledge and mathematics teaching. In addition, Kathirveloon et al (2014.p 1) highlighted that "without full grasp of PCK, teachers may face difficulty in teaching the subject effectively.

5.3.4.3 Design and sequence of instructions

All the three teachers had their instruction designed specifically for computer. Some instructions were too abstract and more teacher centred than learner centred. The teachers in most cases did the talking and, in some cases, engaged learners when teaching the topic. It was evident from the findings, that the learners had challenges understanding some concepts. The instruction and examples were sequenced in a

manner that learners were able to follow. Most examples were from simple to something more complex and grade 9 and 10 textbooks were used as references. The practice of using grade 9 text books when teaching computer to grade 10s was good because it showed that the teachers took in consideration of what the learners learnt previously thus, demonstrating the type of instruction called teaching from known to unknown. For instance, one teacher when introducing the topic asked learners to share what they know about pseudocodes and flow chats.

Specific methods were also used when explaining a concept and during interviews, it was revealed that teachers understood the advantages and disadvantages of using those methods (see Section 4.2.4.3). this is in line with Ball et al (2008) who emphasized that teachers need to sequence particular content for instruction, deciding which example to start with and which examples to use to take learners deeper into the content. They also need to evaluate the instructional advantages and disadvantages of representations used to teach a specific idea. Furthermore, teachers have to decide when to ask for more clarification, when to use a student's remark to make a mathematical point, and when to ask a new question or pose a new task to further learners' learning. Each of these requires an interaction between specific mathematical understanding and an understanding of pedagogical issues that affect student learning (Ball et al, 2008; Hill, H., & Ball, D. L. 2009).

5.3.4.4 Remediating errors

From the lessons observed two teachers were not very effective in remediating learners' errors. Some errors were not attended to immediately but pushed to the next lesson. One of the indicators of teachers with good PCK is that they should not only identify errors but also be able to remediate them. Spotting or recognizing an error is common knowledge that any person can do and sizing up the nature of the error is specialized content knowledge, however, solving them requires interaction with content and teaching. Therefore, teachers should be able to have skills of remediating errors and this work should be done rapidly, often on the fly, because in a classroom, learners cannot wait as a teacher puzzles over the mathematics himself/herself. In addition, no errors should be left unattended as this may affect learners' learning progress. According to Ryan and William (2007) quoted in Nalube (2011, p. 221) argued that "correcting the error directly without addressing the reason for the error

committed does not get the error fixed. Instead, it affects the learner's intellectual mathematical development". Providing solutions to learners' errors does not only benefit the learners but it is also essential to evaluate whether the educational goals are met.

5.4 What instructional strategies do teachers of mathematics use when teaching computer?

Research question two focused on the instructional strategies' teachers use when teaching computer. These strategies were simply the techniques teachers used to help learners become independent strategic thinkers in computer. In order to explore the instructional strategies, open-ended questionnaires were administered, lessons observed and semi-structured interviews were also conducted. The instructional strategies were noted with regards to the way teachers taught flowcharts, pseudocodes, indenting, as well as the way they sequenced the instructions.

5.4.1 Flowcharts

Teachers used basic and common rules to teach flowcharts. This was revealed by the lessons observed. All the three teachers described shapes (elements of a flowchart) with their specific use as a guide for drawing a flowchart. They first read the algorithms, identified the key words in it, picked corresponding shapes and then drew the flowcharts according to the general rules (see Figure 26 for details). Teachers explained the use of shapes in a flowchart as follows: Oval or an elongated rectangle are used to START / BEGIN and STOP/ END a program, parallelogram for INPUT / ENTER / OUTPUT / DISPLAY / PRINT data, a rectangle for PROCESSING data, and arrows for SHOWING THE DIRECTION of the problem-solving process. This was a clear demonstration of PCK in computer by the teachers as it is important to make learners aware of the use of different shapes when drawing a flowchart so that they use those shapes appropriately when solving the questions. This finding is in line with Shulman (1987) who said Pedagogical content knowledge is pronounced and arguably most influential because it identifies the distinctive bodies of knowledge for teaching, that is content and pedagogy. (MoE, 1996) also argued that the essential competencies expected in every teacher are to master the subject matter to be taught and a skill in communicating that subject matter to the learners. In this study, teachers

of mathematics are then expected to be competent in computer and have a skill to communicate the concepts in computer to learners, which the three teachers did on shapes of a flowchart.

However, **T_Y B** used the shapes wrongly when it came to the actual drawing of the flowcharts. For example, the teacher could display/print/output using a rectangle (see Figure 12 for details), when in actual sense a rectangle can only be used for processing/action, as that is where the formula is written to show some processing. This finding is in contrary to Shulman (1987) who expects a teacher in mathematics to not only know what to teach, but why things are taught in that way as also mentioned in Section 5.3.4.2. The teacher in question should have paid attention to the use of each shape (elements of a flowchart) when drawing the flowchart as he explained it to the learners. He should have been consistent and careful to use the shapes correctly as he explained to the learners at the beginning. The researcher at first thought the teacher simply made a mistake in his presentation. However, the teacher continued with the incorrect use of some shapes even in subsequent lessons observed in his classes. Haavold (2011) noted that, a flowchart is just a drawing that uses shapes and lines to show how the different stages in a process are connected to each other. Therefore, teachers must clearly outline the use of these different shapes and apply them correctly is solving problems. Frost (2020) added that, a flowchart lets one to leverage the visual part of the brain to ‘see’ how the algorithm functions. This justifies why teachers must pay attention to all the elements of a flowchart when teaching computer, since it helps learners to see a demonstration of an algorithm. It is also important to teach learners how to read flowcharts so they can integrate them into the mathematics curriculum for improved problem solving.

5.4.2 Pseudocodes

All the three teachers were using the common rules or steps when teaching how to write a good pseudocode (see Figures 28 and 29 for details). The teachers clearly demonstrated that they understood the rules which needed to be followed in order to write a good pseudocode. They started by defining what a pseudocode is and then proceeded in outlining the steps involved in writing good pseudocodes. Some of these rules were: in a pseudocode a statement must be short, clear and readable; the statement must not have more than one meaning (not ambiguous); and the pseudocode

lines should be clearly outlined and indented, among other steps for writing good pseudocodes. Teaching pseudocodes involves instructing learners on how to represent algorithms using a simplified and structured format. By adhering to common rules, teachers ensure clarity in communication, establish a standardized approach to teaching pseudocodes and helps learners develop a systematic and organized approach to algorithmic thinking. This aligns with Ball et al (2008) who emphasizes the importance of teachers having a deep understanding of the subject matter and the pedagogical approaches that best facilitate learning. Brousseau (1997) and Frost (2020) argued that a pseudocode allows one to ‘get the ideas down’ as step by step code-ish statements. For example, getting to the one correct answer to a math problem challenges many learners who may not know where to start or how to get to the answer. Hence the importance of teaching concepts on pseudocodes in a clear and simple way to the learners cannot be overemphasised.

5.4.3 Indenting

Lesson observations and interviews showed that teachers were using two strategies when explaining the concept of indenting in a pseudocode to the learners. The first strategy involved telling learners that when a set of instruction is given on the same aspect, these instructions should start on the same column when indenting. The second one involved advising learners to draw two adjacent lines to indent a pseudocode. When asked questions on the principle of sequence and selection regarding the specific strategies the teachers were using to teach indenting in a pseudocode, what came out was that teachers advised learners to start on the same column when indenting a pseudocode for a set of instructions of the same aspect. From this explanation, it is clear that their guidance on indenting was not as clear to the learners as it should be. This is contrary to Hassen (1995) as cited in Kathirveloo et al (2014) stated that it is important for a teacher to be capable of transforming the knowledge to be taught to the learners in a way that could be understood easily. Hence, teachers needed to give more simplified explanation of this one, with vivid examples to ensure that learners understand the concept. One teacher (**T_YB**) was observed using a ruler to draw two adjacent lines to indent a pseudocode and learners did the same (see Figure 31 for details). Again, this is another questionable way of presenting the concept to the learners. The ideal way of teaching indenting to the learners requires highlighting the

main point which should be followed for one to do the correct thing. The main points is that, all statements showing ‘dependency’ should be indented. For example, statements like while, do, for, if, switch, and many others (Bentley,1983).

5.4.4 Sequencing of instructions

On sequencing of instructions, it was observed that all the three teachers sequenced their instructions in two different ways, which is teaching flowcharts and pseudocodes side by side or teaching flowcharts first, then pseudocodes and vice-versa. In this regard, the sequencing of instruction is not a problem, what is important is for the teacher to know what should come first before the other. The teacher should know whether there is some pre-requisite knowledge that is needed to understand a particular concept or maybe that particular knowledge is already covered by the learners. Looking at flowcharts and pseudocodes, the researcher feels these two can still be taught side by side as some teachers did, as long as learners are made to understand the correct use of shapes (elements of a flowchart) in a flowchart and the general rules for writing good pseudocodes. This can even help learners to see the similarities between flowcharts and pseudocodes, and be able to answer questions easily, whether they have been given a flowchart and asked to write a pseudocode or vice-versa.

There is also no problem in teaching one concept first and then the other, as one teacher did. This is what teachers with adequate knowledge of the topic can do. The findings are in line with McNamara (1991) who suggested that teachers with strong CK may teach in a more interesting and dynamic way whilst those with little CK may shy away from the more difficult aspects of the subject, or approach their teaching in a didactic manner. Shulman (1987) also added that, it is also argued that PCK enables teachers to ease the learning for learners through use of clear explanations, appropriate analogies and presenting learning in interesting, motivating and even entertaining ways. This includes the sequencing of concepts in a particular topic like computer to ease learners’ understanding.

5.5 How do teachers’ mathematical knowledge for teaching computer influence their instructional strategies?

This question focused on establishing how the mathematical knowledge that teachers have for teaching computer (CCK, SCK, KCS and KCT) influence their instructional

strategies. Four themes emerged from analysing of responses in the questionnaire, the lessons observed and during the interviews. These were: organisation, time management, confidence and consistence. These aspects are now discussed in detail.

5.5.1 Organisation

From a number of lesson observations, $T_X A$ was seen to be organized in the way he presented most of his work. The teacher prepared simplified notes for learners to easily understand the topic which is perceived to be too abstract. The examples and exercise were in line with the concepts taught and presented in a way a learner could follow. Attention was given to both the content the teaching. This is a good teaching practice where a teacher simplifies the topic perceived to be abstract without compromising on the content. The practice suggests the inherent connection between a teacher's own grasp of mathematical concepts and their ability to convey those concepts to students. Steele (2013) stated that, teachers also need to know how to represent mathematics content in ways that support student learning of mathematical ideas. Not only that, Sherin (2002) added that teachers need to have abilities to plan, teach, and reflect on practice, such as anticipating student thinking, identifying and addressing mathematical misconceptions or confusions, and making decisions while teaching. This is exactly what the teacher in question did before and when teaching computers to the learners in class. This should be commended and emulated by teachers if we are to instil confidence in learners in mathematics and improve the results.

On the other hand, $T_Y B$ and $T_Z C$, lacked organization and coherence. This is significant because coherence is a fundamental aspect of effective teaching, connecting various mathematical concepts into a meaningful whole. Teachers with strong MKT, as proposed by Shulman (1986) and expanded upon by Ball et al. (2008), should be able to organize content in a coherent manner, ensuring that students understand the interconnectedness of mathematical ideas. However, Teaching was mainly by book, the two teachers kept on checking the textbook for every question and explanation. Using published textbooks is not a problem when teaching, however, over-reliance is a problem. The result of textbook-reliant teaching is that topics are isolated, disconnected and resort to relying on memorizing concepts. Ma's (1999) study highlighted the implicit relationship between teachers' mathematical knowledge and their teaching. In the context of this study, the reliance on textbooks by the two

teachers to an extent of disorganization suggests a potential gap in their pedagogical content knowledge (PCK). In addition, these findings are in line with Kanjinga (2018) and Butty (2001) who established that, pedagogical content knowledge, especially at senior secondary school level remains overwhelmingly teacher-centered with greater emphasis being placed on lecturing and textbook than on helping learners think critically across subject area and applying their knowledge to real world situations. These findings clearly show a significant connection between teachers' Mathematical Knowledge for Teaching (MKT) and instructional strategi

Moreover, the findings are also in line with the study by Mulenga (2019), who revealed that teachers had some incompetence in some of the six domains of the mathematical knowledge for teaching Geometrical Transformations. This clearly shows that teachers have problems with PCK in several topics in mathematics, including computer which was introduced in the Zambian mathematics curriculum following the curriculum revision of 2013.

Teachers can therefore be reminded and advised to ensure that they adequately prepare before teaching any mathematics to the learners. Planning enables a teacher to look at how best a topic or sub-topic can be handled for learners' easy understanding of the concepts. This also helps the teacher to speculate on the challenges that learners may face in understanding the concepts at hand. Teachers who do that are less likely to have limited competencies when it comes to PCK in mathematics. Being organised as a teacher of mathematics dwells more on planning and preparedness to teach, as well as systematic presentation of the subject content as per syllabus demand. Teachers must therefore prepare adequately before teaching computers to the learners. Only when they prepare in advance and consult a variety of sources of information, such as books will they have desired competencies in handling the topic, because proper preparation prevents poor performance.

5.5.2 Time management

From the lesson observations, two teachers were observed to have issues with managing time. The teachers were seen going around the same point when explaining a specific concept, as a result running out of time for more class activities. Due to loss of time some content were not taught as given in the syllabus. **$T_Z C$** for instance, was

unable to give any exercise or attend to all learners' queries, in all his lessons. There was no time given to learners for discussion and for looking for errors. This is contrary to Shulman's (1986) model, particularly the Pedagogical Content Knowledge (PCK) domain, which emphasizes the importance of knowing how to make the subject matter comprehensible to students, which includes structuring lessons in a time-efficient manner. It was also observed that more time was spent on trying to address the mistakes **T_Y B** was making and due to the inconsistency in answering questions (See Figure 12) not much was covered in terms of content as expected.

On the aspect of not adequately involving learners, the findings are contrary to Hiebert (2003) who stated that, allowing a child to creatively invent ways of resolving problems is known as developing algorithmic thinking. Teachers must therefore, endeavor to provide opportunities for learners to do their mathematics and bring out their subjective views on the topic. On the contrary, when time is lost due to ineffective strategies, learners are deprived of valuable interactive learning experiences. Moreover, Morley (1981) added that allowing children to create their own methods to resolve issues stretches their thinking and analytical skills. Hence, it is good for the teacher to avoid time wasting in class by planning the lessons well so that the content in computer can be taught to the learners effectively whilst involving them in lessons within the stipulated time frame.

From the observed lessons, it is evident that the ability to manage time effectively varied among the three teachers and was closely connected to their Mathematical Knowledge for Teaching (MKT). The two teachers with inconsistencies in answering questions and making frequent mistakes faced significant difficulties in terms of content coverage. On the contrary, the teacher who demonstrated a deep understanding of the subject matter was able to navigate through lessons more efficiently, covering a substantial amount of content. It is also important to note that the problems these teachers faced are all in line with planning and preparedness. If planning is done in advance, there can be no issues with time management when it comes to unpacking of mathematics content to the learners. Where planning is well done, there can never be a situation of a teacher meandering about the same point when unpacking the lesson at the expense of other concepts to be taught.

5.5.3 Confidence

One teacher out of the three teachers showed confidence in almost all the lessons. $T_X A$ was confident in teaching the topic. He was able to give clear mathematical explanations and justifications with no hesitation. He was diligent in whatever task at hand. However, $T_Y B$ was failing to justify some concepts on flowcharts confidently, in some cases he was not sure of what he was explaining. $T_Z C$ was also not sticking to his answers when it came to responding to the learners. They were cases where the teacher was challenged by the learners.

Certainly, the varying degrees of confidence observed among the teachers in teaching the topic was attributed to different domains within Mathematical Knowledge for Teaching (MKT). In particular $T_X A$, demonstrated sufficient Subject Content Knowledge, and consistently prepared well before each lesson. This diligent approach not only strengthened $T_X A$'s confidence but also ensured a more effective delivery of the subject matter. The finding is in line with Hill et al (2009), argues that teachers with a solid MKT often exhibit greater confidence and enthusiasm in their instructional practices. This confidence is rooted in a deep understanding of the subject matter and effective pedagogical approaches, fostering a positive and engaging learning atmosphere.

In contrast, teachers $T_Y B$ and $T_Z C$ exhibited a degree of incompetence coupled with inadequate preparation, thereby undermining their confidence in unpacking the topic. Notably, the absence of robust PCK, stemming from irregular preparation and limited research, appeared to be a key factor contributing to the diminished confidence of $T_Y B$ and $T_Z C$. This, in turn, impacted their ability to confidently convey concepts to the learners. For instance, during the explanation of pseudocodes, $T_Z C$ hesitated and struggled to confidently articulate the proper technique for indenting, exemplifying the complex relationship between PCK and teacher confidence.

5.5.4 Consistence

It was observed that some teachers were not consistent with the teaching of some concepts. $T_Y B$ was not consistent with explaining how to draw a flowchart. There was misrepresentation of content for instance, the same shape would be used differently under the same question. The teacher was also not consistent in responding to learners'

questions. In some cases, justifications given to learners were contradicting the teacher's initial explanation of a particular concept. This is as a result of insufficient Specialized Content Knowledge (SCK) and Knowledge of Content and Students (KCS). This finding is contrary to Kathirveloo et al (2014) who stated that Pedagogical Content Knowledge (PCK) plays an important role in classroom instructions. He highlighted that PCK involves three things; teachers' competence in delivering the conceptual approach, relational understanding and adaptive reasoning of the subject matter.

In addition, Hassen (1995) as cited in Kathirveloo et al (2014) added that it is important for a teacher to be capable of transforming the knowledge to be taught to the learners in a way that could be understood easily. In other words, the inconsistency in the teacher signalled lack of skills to transform knowledge in computer in a way a learner could easily understand which is one of the attributes of PCK. Teaching computer should not only be about the teacher demonstrating how to get the correct answer, but also to find ways of how to mediate computer during the teaching and learning process so that learners understand the concepts in computer with ease. Jaworski (1994) stated that, mathematics teaching in the classroom involves the creation of opportunities for learners to learn mathematics. Elements of this include; providing a supportive learning environment, offering appropriate mathematical challenge and nurturing processes and strategies which foster learning. Therefore, the teacher in question needed to do just that so that learners can learn the flowchart, its elements and how to draw it as intended in the school curriculum.

5.6 Summary of the chapter

This chapter discussed the findings of the study on teachers' mathematical knowledge for teaching computer in selected secondary schools of Kasama district. The findings highlight that teachers exhibited varied competencies in teaching the topic. One (1) teacher demonstrated good Pedagogical Content Knowledge (PCK) in teaching computer, while the other two had an average level of PCK. These teachers occasionally made mistakes and struggled to convey certain concepts of the topic with confidence. These challenges seemed to stem from insufficient knowledge in specific areas and a lack of careful lesson planning. The findings also emphasize how a teacher's combined SMK and PCK significantly impact the quality of classroom

teaching and, consequently, influence how well students learn. The next chapter will summarize key conclusions and provide recommendations based on these findings.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter serves to conclude the study and to highlight the major contribution the study has made to research (Section 6.3). Thereafter, the recommendations (Section 6.4) are made in order to enhance teachers' mathematical knowledge for teaching computer at senior secondary school level. Because candidates have exhibited weaknesses in handling computer questions at grade 12 level in national examinations which has greatly contributed to overall poor performance in mathematics (ECZ, 2016; 2017), there is need for teachers to enhance their PCK in computer topic in mathematics. The chapter ends by suggesting further research on computer topic in mathematics education.

6.2 Conclusion

The study explored teachers' mathematical knowledge for teaching the topic computer in mathematics at senior secondary school level, regarding teachers' mathematical knowledge for teaching the topic; their instructional strategies in teaching computer; and how their mathematical knowledge for teaching computer influences their instructional strategies. The exploration of the three teachers' mathematical knowledge for teaching computers revealed significant variations.

It was established that the three teachers had varied competences in teaching the topic computer. One teacher exhibited a more profound understanding and expertise in both Common Content Knowledge (CCK) and Specialised Content Knowledge (SCK), while the other two teachers demonstrated limited expertise in specialised content knowledge (SCK). Additionally, observable differences emerged in the depth of Pedagogical Content Knowledge (PCK) among the teachers, reflecting their individual teaching abilities. One (1) teacher out of the three (3) demonstrated an average level of PCK in computers, whereas the remaining two exhibited insufficient PCK. In essence, these findings emphasise the existence of diverse mathematical knowledge for teaching levels among the three teachers, influencing their effectiveness in conveying concepts in computer.

In conclusion, a collective opportunity for improvement was identified as all three teachers made common mistakes. These included the incorrect use of flowchart elements (shapes), writing formulas in flowcharts without appropriate operational signs as per computer requirements, employing ordinary multiplication and division signs instead of the designated star (*) and slash (/), and a lack of proper guidance for learners regarding indenting. Addressing these shared areas of improvement can contribute to enhancing the overall quality of computer education provided by the teachers.

6.2 Contribution to the field

This study contributes to the academic body of knowledge regarding research in mathematics education and teachers' mathematical knowledge for teaching computers. The study applies Shulman's (1986) and Ball et al.'s (2008) Mathematical Knowledge for Teaching (MKT) framework to analyse teachers' mathematical knowledge for teaching computers. While previous studies have employed the domains of MKT, their focus differs from that of this study. The findings demonstrate how Ball's domains of mathematical knowledge for teaching influence instructional strategies, in terms of organization, confidence, time management, and consistency. Moreover, the study suggests that Jaworski's teaching triad can be integrated within MKT. Exploring teachers' Mathematical Knowledge for Teaching highlights how these domains influence each other, ultimately affecting the quality of mathematics instruction.

6.4 Recommendations

The following recommendations were made in the light of policy, practice, and further research.

6.4.1 Policy

MoE through TCZ should monitor the activities and quality of Continuing Professional Development (CPDs) that teachers of mathematics conducting to ensure that new topics such as computer are focused on so that the teachers become more grounded in SMK and PCK

6.4.2 Practice

1. Secondary schools to intensify School Based Continuing Professional Development (SBCPD) so that teachers of mathematics can share knowledge regarding teaching of computer topic at senior secondary level.
2. Teachers should be strict with learners' use of elements of a flowchart, and with indenting when answering questions on flowcharts and pseudocodes, respectively.

6.5 Further research

1. There is need to explore learners' views on teachers' mathematical knowledge for teaching the topic computer in mathematics.
2. There is need to compare learners' performance in computer and teachers' content knowledge.

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APPENDICES

Appendix 1: Projected Research Budget

S/N	DESCRIPTION	QUANTITY	UNITY PRICE (ZMW)	TOTAL COST (ZMW)
1	Stationery - Reams of paper - Box of pens - Flash disk 32GB	02 01 01	60 30 175	120 30 175
2	Research equipment -MP 3 Recorder -Typing proposal and report -Printing: copies of proposal and Report. - Binding: copies of proposal and report - Communication processes (air time)	01 08 08 08 - -	800 200 200 100 600	900 1600 1600 800 600
4	Research cost - Transport to and from kasama. - Lodging per night - Feeding per day	4 14 14	360 180 80	1440 2520 1120
5	- Ethical clearance - Editing	01 01	500 1800	500 1800
5	Miscellaneous			800
6	GRAND TOTAL			K13,90

Appendix 2: Proposed Work Plan and Time Table

S/N	ACTIVITY DETAILS	DATES	DURATION
1	Preparation of research proposal	September - October, 2020	Eight weeks
2	Development piloting recasting of data collection instruments	June, 2021	Two weeks
3	Data collection processing and analysis	July - September 2021	Ten weeks
4	Report writing, typing and editing	September / October- November 2021	Ten weeks
5	Proof reading, production & submission of first draft	December 2021	Three weeks
6	Refining and submission of second draft report	January 2022	Three weeks
7	Refining and presentation of final draft	February / March 2022	Four weeks

Appendix 3: Letter of Permission for Head Teachers

Kasama boys secondary school
Box 410235
Kasama.

Date:2020.

The Head teacher,
.....Secondary School,
P.O. Box.....,
Kasama.

Dear Sir/ Madam,

Re: Request for Permission to conduct research in your school

I am a student at the University of Zambia (UNZA) pursuing a Master's degree in Mathematics Education. As a requirement for my studies, I am expected to carry out some research and compile a report thereafter. A research that I intend to conduct is titled *teachers' mathematical knowledge for teaching computer in selected secondary schools*. This will call for conducting class observation of teachers teaching process and interviewing them after wards. I therefore, request permission to conduct my study in your school. Kindly be rest assured that the identities of the school and teachers will be highly protected in order to comply with Ethical requirements laid down by University of Zambia.

Thank you for the consideration.

Yours Faithfully

MULENGA SERAH

Appendix 4: Questionnaire for Teachers

Dear participant,

I am a post graduate student carrying out an academic study where your participation is very important.

I humbly request you to participate in the study by answering the questions in the questionnaire. The information that will be obtained will be treated with the highest confidentiality and shall not interfere in any way with your work but will be used for academic purpose only.

Instructions:

- Fill in all the spaces below
- Ask where you are not clear
- 1. What subject areas and year levels do you teach?

- 2. How long have you been teaching?

- 3. How long have you been teaching computer?

- 4. At what grade level have you been teaching computer?

- 5. What type of school do you work in? (public, private, independent, religious)

- 6. What are the important pre- requisite topics that are needed for a pupil to understand the concepts in computer (algorithms)?

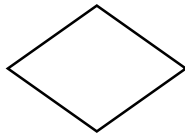
7. If a pupil did not understand the topics mentioned above, if any, what are some of the challenges a pupil might face?

8. What type of knowledge do you think a teacher of mathematics should have to teach computer?

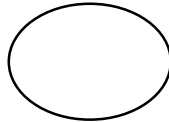
9. What do you understand by the term algorithm?

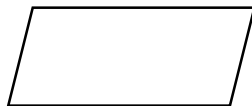
10. What different ways of presenting an algorithm do you know?

11. What name is given to each of the following symbols in computer?



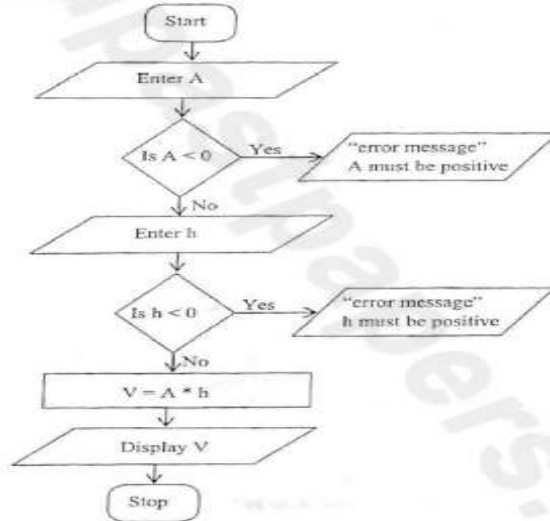






12. A pupil has been asked to answer the following question in the final examination. What answers do you expect him/her to give?

(b) The flow chart below shows the steps in calculating the volume of a solid given the base area (A) and height (h).



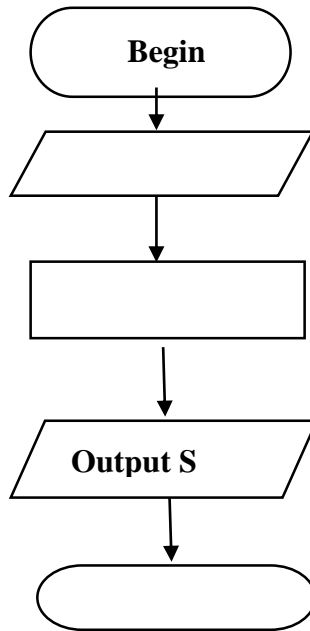
Write the corresponding pseudocode for the flow chart given above. [5]

source:ECZ (2019/2,p.5)

13. What difficulties do your learners experience in learning computer?

14. How would you help your learners overcome the difficulties mentioned in 13 above if any?

15. A learner has been asked to complete a flowchart below concerning calculating the curved surface area, S , of a cone with base radius r and slant height l . Provide the possible answers he/she would give.



16. a) Describe the professional development you have attended recently in relation to computer?

- b) Why did you choose to attend the mentioned in (a) above if any?

- c) How will you use it to benefit your students?

17. What are some of the things that you suggest for teachers to do for them to effectively teach computer?

Appendix 5: Lesson Observation Schedule

Dear Participant,

I am a postgraduate student at the University of Zambia (UNZA) pursuing a Master's degree in Mathematics Education. I am conducting a research on the topic, "*teachers' mathematical knowledge for teaching computer in selected secondary schools*" Kindly feel free as I observe the lesson. This study is purely for academic purposes and not meant to cause you any mental or physical harm. I therefore, encourage you to participate freely.

School code: _____ Teacher's code: _____ Grade: _____

Time: _____ Number of Learners: Boys: _____ Girls: _____

Observation sheet: _____ Topic: _____ S/Topic: _____ Date: _____

Domain	Activity	Teacher's competences by theme	Comment
Common content knowledge (CCK)	- Definition of concepts in computer		
	- Recognize inaccurate definition from textbooks and knowing when students have answers wrong.		
	- Correct use of terms and notations for computer when speaking and writing at the board.		
Specialized content knowledge (SCK) & Mathematical challenge (MC)	- Sizing up the nature of the error		
	- Aptitude to explain as well as to justify reasoning (provision of mathematical explanations for common rules and procedures in computer, recognizing and explaining conceptual differences and relationships, explaining the understanding of concepts, Justifying rules and use of specific methods).		
	- Capacity to represent computer concepts in different forms		
Knowledge of content and students	-Type of examples given (interesting and Motivating).		

(KCS) & Sensitivity to students (SS)	- Familiarity with students' errors.		
	- Ability to hear and interpret students' emerging and incomplete thinking.		
	- Interaction between specific mathematical understanding and familiarity with students and their mathematical thinking.		
Knowledge of content and teaching (KCT) & Management of learning (ML)	- design specific instruction for computer.		
	- Remediating the students' errors.		
	- Instructional strategies when teaching a specific concept.		
	- Sequencing of particular content for instruction (deciding which example to start with and which examples to use to take students deeper into the content.		
	-Interaction between specific mathematical understanding and an understanding of pedagogical issues that affect student learning of computer.		

Appendix 6: Interview guide for teachers of mathematics

Interviewer: _____

Interviewee: _____ **sex** () **school:** _____

Date: _____

Start time: _____

Dear participant,

Please note that this is a purely academic study, the information that will be obtained from this interview will be treated with the highest confidentiality and shall not interfere in any way with your work but will be used for academic purpose only.


Review of recorded lesson and the teachers' answered questionnaire. Uses it as a basis for conversation.

1. Please take me through the lesson, what were you doing and what were you hoping to achieve?
2. What does the use of such [as seen in the video] methods mean for you?
3. Why do you think the strategies you use are important?
4. What other instructional strategies do you normally use in the classroom when teaching computer?
5. Why do you use them?
6. When using these, what do you hope to achieve?
7. How were you able to detect patterns in students' errors if any?
8. How were you deciding which example to start with?
9. Why do you think computer is important in mathematics?
10. What challenges do you face when teaching computer if any?
11. What possible measures to overcome the challenges if any?
12. Ways of improving the teaching and learning of computer
13. How are pupils going to benefit from learning computer in mathematics? (in other subjects, in real life and in their future careers)

End time: _____

Thank you for your time and participation.

Appendix 7: Clearance letter for data Collection from the University of Zambia



THE UNIVERSITY OF ZAMBIA
DIRECTORATE OF RESEARCH AND GRADUATE STUDIES

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APPROVAL OF STUDY

14th May, 2021

REF NO. HSSREC: 2021-APRIL-024

Ms Serah Mulenga
University of Zambia
C/o School of Education
LUSAKA

Dear Ms Mulenga,

**RE: "TEACHERS' MATHEMATICAL KNOWLEDGE FOR TEACHING COMPUTER
 IN SELECTED SECONDARY SCHOOL OF KASAMA DISTRICT, ZAMBIA"**

Reference is made to resubmission of your protocol dated 28th April, 2021, HSSREC resolved to approve this study and your participation as Principal Investigator for a period of one year.

Review Type	Ordinary Review	Approval No. HSSREC: 2021-APRIL-024
Approval and Expiry Date	Approval Date: 14 th May, 2021	Expiry Date: 13 th May, 2022
Protocol Version and Date	Version - Nil	14 th May, 2021
Information Sheet, Consent Forms and Dates	• English,	To be provided
Consent form ID and Date	Version - Nil	To be provided
Recruitment Materials	Nil	Nil
Other Study Documents	Questionnaire.	
Number of Participants Approved for Study		

Towards Improving Service and Excellence in High Education Beyond Fifty Years