COGNITIVE CONFLICT IN MATHEMATICS TEACHING AND LEARNING IN PUBLIC SECONDARY SCHOOLS IN EMBU WEST SUB-COUNTY, KENYA

DICKENS OKACH NGICHO

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

Signature…… Date……

Dickens Okach Ngicho
Department of Education
E551/1216/2018

This thesis has been submitted for examination with our approval as university supervisors.

Signature…… Date……

Dr. Simon Karuku
Department of Education
University of Embu

Signature……. Date……

Dr. Madrine King'endo
Department of Education
University of Embu

DEDICATION

The work is dedicated to Almighty God for His care and protection to me as well as His continuing guidance to my footsteps along the right path towards using the gifts and talents I have received from Him to study. Also, the work is dedicated to my family as well as my late parents. Moreover, the work is dedicated to my brothers, sisters, and all my relatives and friends. My parents used to encourage me to study even in difficult times so that I can achieve the benefits of education. My brothers, sisters, and all my relatives and friends as well made me happy during this work as they continue to encourage me to work hard.

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ABBREVIATIONS AND ACRONYMS

CAME	Cognitive Acceleration through Mathematics Education
CASE	Cognitive Acceleration through Science Education
CCK	Common Content Knowledge
KCC	Knowledge of Content and Curriculum
KCS	Knowledge of Content and Student
KCSE	Kenya Certificate of Secondary Education
KCT	Knowledge of Content and Teaching
KSA	Knowledge, Skills and Attributes
MOEST	Ministry of Education, Science, and Technology
NACOSTI	National Commission for Science, Technology, and Innovation
PBI	Processed Based Instruction
PCK	Pedagogical Content Knowledge
SCK	Specialized Content Knowledge
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences
STEM	Science, Technology, Engineering, and Mathematics

DEFINITION OF OPERATIONAL TERMS

Accommodation. It infers to the process of making use of existing ideas during mathematics teaching and learning with new experiences so that new experiences that seem to be challenging to students can fit in their mind with the previous knowledge.

Assimilation. It implies to the process of making use of the new experiences into the existing idea in the student's mind during mathematics learning so that they can understand and apply the concepts learned.

Cognitive conflict. It is viewed in this study as a teaching-learning strategy that aims at increasing student ability to understand concepts, improve reasoning skills, and develop new knowledge for critical problem solving as a result of a situation where they are confronted with a discrepancy between their existing knowledge and new information.

Cognitive structure. It describes to any mental representation that a student uses to organize knowledge, beliefs, and values acquired during mathematics learning so that the information received is organized for learning and recall.

Misconception. It refers to a mistaken thought, idea, and misunderstanding of mathematical concepts by students and therefore, it requires the teacher to adequately prepare on how to manage them during mathematics teaching and learning.

Scaffold. It stands for the act in which teachers of mathematics employ various strategies to support students to reach a better understanding of mathematics skills that they would not have attained without assistance.

Schema. It refers to the network of mathematical and other related knowledge that is built by the teacher and students during mathematics lessons around a core concept.

Student's attitude. It refers to the way a student reacts to situations when mathematics appeared difficult or simple.

ABSTRACT

Cognitive conflict is widely recognized as an important factor in the process of conceptual change and can be effectively utilized to promote the learning of mathematical concepts. However, there has been little research that has examined how learners experience cognitive conflict as well as how teachers utilize this phenomenon during mathematics teaching. This study aimed at investigating the cognitive conflict in mathematics teaching and learning in public secondary schools in Embu West Sub-County, Kenya. Cognitive dissonance theory guided the study, and a mixed method research design was adopted. A population of 25 public secondary schools with 2800 Form Two students and 48 Form Two teachers of mathematics were targeted for the study. A census of all the public secondary schools in Embu West Sub-County was conducted, with the Yamane model being used to select students' participants for the study. Specifically, the sample size was 350 Form Two students and 48 teachers of mathematics. Also, a total of 68 students (32 females and 36 males) drawn from 17 secondary schools (6 single-sex and 11 mixed-sex) participated in the interviews. Purposive sampling was used to select students for the study based on their performance in their most recent mathematics examination result where only top students were selected. Data were collected using surveys and one-on-one semi-structured interviews. The research instruments for the study were questionnaires and interview schedules. To test the validity and reliability of the research instruments, the instruments were piloted with 2 teachers of mathematics and 20 Form Two mathematics students drawn from a secondary school outside the study area. Qualitative data were first transcribed, then coded and the codes were organized into categories and finally the categories organized into themes. Quantitative data were analyzed using SPSS for descriptive and inferential statistics. The findings of this study indicate that students experienced cognitive conflict in three different ways; namely, a moment to (co)construct one's mathematical meaning, confusion as a result of teacher's behaviorist stance, and a fleeting moment of magic. The study also established that there are significant gender differences in learners' approaches to cognitive conflict where male students were found to experience more cognitive conflict as compared to female students. Therefore, the study underscores the need for teachers to utilize cognitive conflict by encouraging group work and other cooperative learning strategies among students by giving them tasks that provoke critical thinking so that as students work on those tasks, their naïve understandings of the concepts are challenged. The findings of this study are significant to teachers of mathematics as these will help them reflect on their own strategies for scaffolding mathematics learning using cognitive conflict, thereby contributing to an improvement in the quality of mathematics learning by students. The findings are also relevant to mathematics educators and instructional leaders as they provide insights on how to design quality pre- and in-service training programs for teachers of mathematics.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Mathematics is recognized as an important subject in the school curriculum world over as it is applied to everyday life situations and acts as a 'gatekeeper' for future academic and career progression (Bryk & Treisman, 2010). Inability to solve mathematical problems by students may lead to cognitive conflict which is a situation where a student is confronted with a discrepancy between their existing cognitive elements (such as attitudes, perceptions, knowledge, and behaviors) and new information or idea (Waxer & Morton, 2012; Zazkis & Chernoff, 2006). Under this situation, it is assumed that the students are supposed to reconsider and change their way of thinking about the concept and adopt a new method (Maume & Mathews, 2000).

Cognitive conflict is also students' awareness about a contradiction in their cognitive structure during mathematics learning when new concepts contradict their prior knowledge (Zazkis & Chernoff, 2006). During learning, cognitive conflict should motivate learners to possess in-depth understanding of the concept taught to solve problems as opposed to memorization (Adnyani, 2020). Normally, this situation occurs when students have a given idea and attitude about how a problem should be solved that makes them feel that the way the concept is being explained during mathematics learning is not correct. Cognitive conflict can be viewed as a learning strategy that aims at increasing student ability to understand concepts, improve reasoning skills, and develop new knowledge for critical problem solving (Chow & Treagust, 2013).

Rahim et al. (2015) argued that there is a need to correct students' misconceptions since failure to do so can hinder them understanding of the concept being taught to them and as a result, they will memorize the content. Cognitive conflict should aim at overcoming the students' misconceptions to ensure improved mathematics learning. As noted by O'Brien and Iannone (2018), there is a need to extend and deepen teachers' professional

understanding of teaching and learning practices and strategies that are interrelated with performance. Therefore, there is need for research on teaching and learning that can improve students' achievement as well as ensure improved teacher-student experience at a micro-level inside the classroom (Tinto, 2012). Additionally, Murphy et al. (2019) underscore the need for studies that can investigate how teachers in various academic disciplines modify their teaching methods towards responding to the needs of their students as well as how the teachers incorporate the variety of teaching methods to ensure students engagement during learning.

Teachers of mathematics can utilize cognitive conflict to facilitate student mastery of content during teaching so that students can possess good critical thinking skills that they will use in solving problems (Maharani & Subanji, 2018). In addition, cognitive conflict in mathematics should equip students with the ability to explore and solve mathematics problems critically which can result in good academic achievement (Herawaty et al., 2019). As noted above, mathematics is a subject that helps learners with problem solving skills required in everyday lives, yet it is poorly performed at the Kenya Certificate of Secondary Education (KCSE) examination (Nakhanu, 2012). Very few studies have explored how teachers can utilize cognitive conflict moments in the mathematics classroom to support student learning (Mulungye et al., 2016).

Students' preconceived knowledge can affect their mathematics learning leading to cognitive conflict. Mulungye et al. (2016) argue that students construct misconceptions from their experiences that they cannot give up easily. For example, they might misinterpret $(a+b)^5$ as a^5+b^5, which can lead to poor academic outcomes if the situation is not corrected during a teacher-student engagement. Good mathematics learning will result in a good academic outcome and vice versa. Since few studies have been done on cognitive conflict in mathematics teaching and learning in Kenya, novel strategies of teaching mathematics such as cognitive conflict still needs a study so that the findings can be used to improve mathematics teaching and student mathematics learning (Mulungye et al., 2016).

Most of the research done in mathematics education in Kenya is on other factors that affect students' performance in mathematics other than cognitive conflict. There is poor student

mathematics learning in Kenya as evidenced by poor grades scored in KCSE (Kivuti, 2015; Mulungye et al., 2016; Nakhanu, 2012). Embu West Sub-County has not been an exception as shown by the mean score for mathematics in KCSE has been in grade D since 2014 up to 2018 as evidenced in Table 1.1 below.

Table 1.1: Performance in Mathematics at KCSE for Embu West Sub-County between 2014 and 2018

Year	Mean Score	Mean Grade
2014	3.3648	D
2015	3.41	D
2016	2.83	D
2017	3.33	D
2018	3.19	D

Source: Embu West Sub-County Education Office

This suggests that the mean score in mathematics in Embu West Sub-County is likely still at D, hence there is a need to conduct a study in this county, to determine ways that will improve mathematics learning (Njagi, 2013). Such performance necessitates this study to focus on cognitive conflict in mathematics teaching and learning in public secondary schools in Embu West Sub-County, Kenya.

1.2 Statement of the Problem

The value of mathematics to an individual and society is acknowledged worldwide since the subject is applied by each individual in the society on various daily activities. The complex ways in which students perceive themselves in the context of mathematics learning is critical to understand since when students bring their divergent perspectives to a problem solving situation, the interaction causes them to consider questions that might not have otherwise occurred to them. This stimulus could cause students to identify gaps in their mathematics understanding, which they would then be in a position to address. This

type of cognitive conflict has the potential to lead to productive shifts in student understanding and to elicit elaborate explanations from students that are associated with learning. This is so because when students work together to solve a mathematical problem, they can provide support for each other, and thereby solve problems that would be just beyond their reach if they were working alone. Few studies have explored how teachers could utilize the phenomenon of cognitive conflict to support student conceptual understanding during mathematics learning.

Poor conceptual understanding leads to poor academic outcomes that is evident in the KCSE where mathematics has been poorly performed in many secondary schools in Kenya. In particular, Embu West Sub-County has been registering poor student performance in mathematics as compared to other science subjects (Njagi, 2013). Considering these trends in performance there is a need to identify more strategies for supporting student learning towards quality academic achievement and the use of cognitive conflict may be a noble strategy. Also, this will aid in raising teachers' and teacher educators' consciousness of the value of cognitive conflict as a strategy for scaffolding student learning towards critical problem solving that promotes conceptual understanding. Some researchers had recommended further research in Embu West Sub-County to explore ways of improving students' mathematics learning that was to result in a good performance in mathematics. This study, therefore, investigated the cognitive conflict in mathematics teaching and learning in public secondary schools in Embu West Sub-County, Kenya.

1.3 General Objective of the Study

This study sought to explore how cognitive conflict is manifested and how it could be utilized in mathematics teaching and learning among secondary school students and teachers in Embu West Sub-County, Kenya.

1.4 Specific Objectives of the Study

The study was guided by the following specific objectives:

1. To investigate manifestations of cognitive conflict in mathematics.

2. To compare gender differences in learners' approaches to cognitive conflict in mathematics.
3. To determine the level of teacher preparedness to scaffold mathematics learning using cognitive conflict.

1.5 Research Questions of the Study

The study was guided by the following research questions:

1. How is cognitive conflict in mathematics manifested?
2. Are there significant gender differences in learners' approaches to cognitive conflict in mathematics?
3. To what extent are teachers prepared to scaffold mathematics learning using cognitive conflict?

1.6 Justification of the Study

Poor performance in mathematics as a subject is an area of concern in Kenya since many researchers have indicated that studies are needed to provide ways on how problems with poor performance in mathematics can be addressed in Kenya holistically. In particular, in Embu West Sub-County in Embu County, studies are needed to provide ways on how mathematics learning can be improved since few studies that had been carried out on factors like students' motivation, students' attitude among others had directed researchers to conduct studies on how quality academic achievement can be obtained in mathematics (Kivuti, 2015; Njagi, 2013). The scholars stressed a need to conduct a study that can assist teachers to improve their pedagogical skills to promote students' conceptual understanding of mathematical concepts for better performance. Therefore, this study focused on the cognitive conflict in mathematics teaching and learning in public secondary schools to provide useful information on how mathematics learning can be improved. This is because cognitive conflict can affect a student's acquisition of mathematical concepts that can leads to poor learning as well as a low academic outcome if the situation is not identified and corrected during teacher-student interaction as well as student-student interaction during problem solving situations (Rahim et al., 2015). The findings from this study provides

insight to administrators, mathematics educators, and mathematics teachers onto how cognitive conflict can be used to improve mathematics teaching and learning to ensure better academic achievement by students.

1.7 Significance of the Study

This study is important in three respects: the study is expected to help instructional leaders and mathematics educators with insights on how to design quality pre- and in-service training programs for teachers of mathematics. Also, the information obtained will help these leaders in coming up with relevant instructional strategies in mathematics to help learners in resolving cognitive conflict. This will lead to improved academic achievement in mathematics. Secondly, the study provides the teachers with strategies to resolve cognitive conflict in mathematics teaching. Lastly, the study is expected to help students develop problem solving skills, teamwork, communication skills that will be applied across a range of occupational fields for sustainable development. This is because mathematics education is key in national development as it promotes creativity and critical thinking by students that are important for national development (Yuanita et al., 2018).

1.8 Assumptions of the Study

The study assumed that the participants were honest in giving relevant information on cognitive conflict and how it affects mathematics teaching and students' mathematics learning. The study also assumed that the participants were able to recall and articulate their experiences with cognitive conflict in mathematics.

1.9 Limitations and Delimitations of the Study

The study was conducted in selected secondary schools in Embu West Sub-County. As such, the findings may not be generalized to all public secondary schools in Kenya. However, the study provides useful insight into how teachers can make use of cognitive conflict to promote students understanding of mathematical concepts.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The study employ narrative approach to give narrative literature on cognitive conflict in mathematics that supports this study since the method can be used to synthesize both quantitative and qualitative studies (Snilstveit, et al. 2012). To begin, this chapter gives the status of mathematics teaching and learning as well as general information about the cognitive conflict in mathematics teaching and learning. The chapter continues by giving details about learners' manifestations of cognitive conflict in mathematics learning and gender differences in learners' approaches to cognitive conflict in mathematics. It concludes by giving information about teacher preparedness to scaffold mathematics learning using cognitive conflict and theoretical framework as well as the conceptual framework used in the study.

2.2 Status of Mathematics Teaching and Learning

Globally, mathematics pass rates at school level have been a much-discussed and researched issue. This is because mathematics educators have realized the importance of mathematics in that the subject helps students to adapt to social life, participate in production practices as well as further learning (Li, 2019). Teachers and researchers alike are tasked with the responsibility of alleviating learners' challenges associated with the learning of mathematics. Good mathematics learning requires good epistemological beliefs on both teachers and students, improved teaching strategies by teachers like ensuring adequate explanation of content, motivation to students during teaching, and passing of the subject structure so that the students can understand and use mathematics and its application (Samuelsson & Samuelsson, 2016).

Mathematics learning is evidenced by the development of students' conceptual understanding and procedural knowledge on how to solve different problems for quality academic achievement (Maharani & Subanji, 2018). There is a need to improve

mathematics learning in Africa by ensuring improvement in learners' outcomes (Bethell, 2016). In Kenya, most studies in mathematics have indicated that students' performance in the subject is generally poor (Kivuti, 2015; Mulungye et al., 2016; Nakhanu, 2012; Njagi, 2013). Therefore, the researchers have directed future studies to focus on ways that will improve the teachers' pedagogical skills, as well as students' conceptual understanding of mathematics that will improve students' performance in tests and examination in the subject. Teachers and researchers world over are pursuing innovative techniques for improving the understanding of and increasing the pass rates in mathematics. Many of the strategies identified for improving performance in mathematics are learner-centered and include problem solving, inquiry-based, discussions, questioning of content, and cognitive conflict.

2.3 Cognitive Conflict in Mathematics Teaching and Learning

Cognitive conflict is a learning method that helps to answer students' needs by making them work hard and exploit their thinking when solving a problem that contradicts their cognitive structure (Susilawati et al., 2017). Swan et al. (2006) argued that teachers should employ Cognitive Acceleration through Science Education (CASE) and Cognitive Acceleration through Mathematics Education (CAME) as programs that help to scaffold mathematics learning based on cognitive conflict. In addition, teachers can also make use of cognitive conflict based learning models that can promote conceptual understanding by students. For instance, cognitive conflict based learning model with four stages that include: activation of preconceptions and misconceptions that forms the first stage when the conflict is invoked during mathematics learning, presentation of cognitive conflict, discovery of the concepts and equations to solve the conflict, and reflection stage (Mufit et al., 2018). Lee et al. (2003) also argued that conflict due to different cognitive structures will lead to a shift in students understanding of concepts during mathematics teaching and learning so that they can develop new knowledge.

Cognitive conflict is considered as a learning method that is interactive, inspiring, fun and challenging to students. This is because it will motivate both the teacher and learners to come up with new ideas that will help in solving problems for a better understanding of

concepts (Baddock & Bucat, 2008). Teachers of Mathematics should possess all the knowledge about mathematics so that they can teach students the basic knowledge and skills of mathematics and scaffold mathematics learning by employing cognitive conflict that will improve students' mathematical thinking habits as well as their mathematical literacy (Li, 2019).

Mathematics teaching and learning based on cognitive conflict can improve students' ability to solve mathematical problems, develop critical thinking, and improve their communication skills (Widada et al., 2018). Due to cognitive conflict learners have difficulties in solving mathematical problems and hence teachers need to be focused on learners' mathematical errors and correct them during teaching and learning (Makonye & Khanyile, 2015). In utilizing cognitive conflict during teaching, teachers of mathematics need to have a methodology to develop concepts, enquiring minds of students, and have problem solving ability. This will aid in identifying moments where students realize that something is not right and pedagogically figure out what might be the cause of the problem to them during mathematics learning (Mulungye et al., 2016).

In mathematics teaching and learning cognitive conflict makes students aware of a discrepancy between their existing cognitive framework and new information (Shahbari & Peled, 2015). This situation stimulates the learning process by making learners to get motivated to learn how new experiences can be used to solve the problem (Finau et al., 2018). To achieve this, learners need to work together among themselves and with the help of the teacher so that they can overcome the challenge of cognitive conflict (Njenga et al., 2017).

2.4 Manifestations of Cognitive Conflict in Mathematics

Cognitive conflict, as mentioned earlier, is a situation where students realize a contradiction in their cognitive structure during mathematics learning when new concepts contradict their prior knowledge (Finau et al, 2018). The students who experience cognitive conflict during mathematics learning are confused. Also, they like to play with a pencil or a pen as well as tapping a table using a pen, and they always rub their nose (Sayce, 2010). Such students are likely to get an incorrect answer for a problem being solved (Wyrasti et

al., 2016). The incorrect answer results from student's beliefs; that is, conceptions that are in cognitive structures, where cognitive structures are mental processes that different individuals use to process and understand information stored in short-term and long-term memory (Lee & Kwon, 2001). Lee and Kwon (2001) gave three different types of cognitive conflicts experienced by students in the classroom during teaching and learning that include: an internal cognitive conflict that occurs between two competing ideas during the learning process. An external social cognitive conflict that results from sources of information, and an internal-external cognitive conflict that arises between an internal and external event.

Cognitive conflict with students in the classroom can also results from mathematical tasks that the teacher asks them to do. For example, Sayce (2010) report on classroom work noticed that students experienced cognitive conflict when they were asked to plot (1, 3), (2, 6) and (3, 9) on the circular grid and then to consider looking at some sets of the points with a common link. Also, cognitive conflict may result from the way a mathematical problem is presented, for example, $4x + y = 6, 6x = y + 14$ (Sayce, 2010). According to her, students argued that they were at first unaware of what to do as some started by looking at the value of x while others started by looking at the value of y. Another possible source of cognitive conflict in mathematics is in Algebra, where theorems are to be proved. The role of the teacher in these instances is to help the students solve their misconceptions so that learning can occur (Johnston-Wilder et al., 2016).

Cognitive conflict is also experienced by students when they are confronted with a situation that is incompatible with their understanding of prior concepts (Lee & Kwon, 2001). According to Lee et al. (2003), students illustrated that this situation makes them feel anxious and show an interest in solving a problem. Lee et al. (2003) emphasize that based on epistemology, students will not change alternative theories unless they experience cognitive conflict that will aid in challenging their misconceptions. If the misconceptions are not properly solved then students perceive mathematics as a very difficult subject in the school curriculum because they will have an incorrect answer. Lee and Kwon (2001) gave the psychological signs of cognitive conflict during teaching and learning. The

situation results in uncertainty, doubt, perplexity, contradiction, conceptual incongruity, and being irrelevant to learners during mathematics learning.

Haggarty (2013) explained some variables about cognitive conflicts in mathematics education, such as, prior knowledge by the learners, motivation, and interest that affects both the learner and the teacher, epistemological beliefs, values, and attitudes towards learning and teaching strategies, as well as cognitive engagement in learning tasks being done. He also noted that there are other factors related to the social context where learning takes place that also contributes to cognitive conflicts and they include, roles of peers, communication problems, and thinking in different forms about concepts.

2.5 Gender Differences in Learners' Approach to Cognitive Conflict in Mathematics

Gender difference is a crucial issue in student learning because some researchers have indicated in their literature that due to socialization males have been found to have higher interest in mathematics than females that led males to develop more confidence in mathematics than females (Chen et al., 2016). Understanding mathematics always follow significant leaps rather than a smooth and stable path (Pratiwi et al., 2019). This can make many female students to have a negative attitude towards science that can result from their poor mathematics learning (Hacieminoglu, 2016; Samuelsson & Samuelsson, 2016). Due to this, teachers should consider students' knowledge of the subject before they decide what they should be taught and how. This will help in identifying students' knowledge from other areas previously covered so that the confusion experienced can be used to improve student mastery of the content and applied to the current knowledge that will improve their academic outcomes (Susilawati et al., 2017).

Female students may also experience more mathematics anxiety than male students hence during teaching, different intervention methods need to be used by the teacher to ensure that students are supported during the cognitive conflict that will help to reduce anxiety (Devine et al., 2018). This can also be achieved by employing processed based instruction (PBI) by teachers that ensure differentiated instruction based on students need by teaching them how to learn and solve problems critically. For teachers to have this teaching-learning method, they need to undergo in-service training so that they can gain new skills required

to solve cognitive conflict situations during students' mathematics learning (Ashman & Conway, 2017).

Cognitive researchers explained that cognitive conflict may be the reason as to why female students have lower self-efficacy in mathematics learning (Zeldin & Pajares, 2000). This results in their underrepresentation in mathematics related employment areas. Also, men have high self-efficacy in mathematics due to high science ability and high interest in mathematics related careers. As a result, they try to develop good cognitive strength to solve mathematics that increases their representation in mathematics job opportunities (Samuelson & Samuelson, 2016; Wang & Degol, 2017).

Students need to develop good problem solving skills in mathematics because it will help in decreasing learners' stress, anxiety, and promote mathematics learning by solving misconceptions. Cognitive conflict can lead to a lack of understanding of mathematical concepts by students who finally get confused during the lesson (Maharani & Subanji, 2018). Maharani and Subanji (2018) also noted that cognitive conflict should be useful during teaching and learning as it will help in decreasing students' confusion by developing additional skills for better problem solving. Cognitive conflict is an important situation to be utilized by teachers so that learners can gain new concepts for in-depth understanding (Vygotsky, 1978). If the misconceptions are not properly solved, mathematics learning by students as well as their academic outcome will be poor (Barke, 2013).

2.6 Teacher Preparedness to Scaffold Mathematics Learning using Cognitive Conflict

Teacher's preparedness is the same as readiness which means the belief, ability, and capability of the teacher to handle new situations that are different from the way learners think of a concept (O'Neil et al., 2013). Teaching and measuring cognitive readiness deals with, the need of instructional and assessment strategies, need for a theory that gives ways on how evaluation is done and it also increases knowledge to teachers about cognitive readiness that is viewed through Knowledge, Skills, and Attributes (KSA) lens (O'Neil et al., 2013). Cognitive conflict is the most influential factor in acquiring new knowledge because if the situation is well utilized then the students will overcome misconceptions through new constructions (Fraser, 2007).

In employing cognitive conflict to scaffold mathematics learning, teachers of mathematics are advised to develop their lesson plans and student worksheet by outlining activities that promote conceptual understanding by making the lesson learner-centered. This will help during cognitive conflict situations in mathematics teaching and learning as students will be able to identify their mistakes and complement new ideas taught during the lessons that are useful for current and future problem solving (Putra et al., 2019). Furthermore, teachers need to make use of cognitive conflict models that have general patterns in helping students to gain new knowledge. These patterns include; exposing alternative framework, creating conceptual cognitive conflict, and encouraging cognitive accommodation (Osborne, 1993).

According to Piaget (1985), new constructions are a result of three mental processes that include: assimilation, accommodation, and equilibration. These processes help students to make use of new knowledge to ensure a major change in the existing cognitive structure. To achieve this, the teacher should make use of a teaching strategy that promotes students' understanding from procedural to a structural understanding of concepts (Fraser, 2007). Therefore, teachers of mathematics are also encouraged to apply various scaffolding supports in mathematics teaching that includes; conceptual, procedural, and metacognitive supports that promotes students' engagement to ensure effective learning. In this, conceptual scaffolding will help students in the selection of key knowledge as presented by the teacher and arrange the gained knowledge in a manner that will allow them to solve mathematical problems that require the synthesis of that idea (Kojo et al., 2018). On the other hand, procedural scaffolding strategy entails what should be done to obtain a solution to a problem. In this teachers should be able to give students moderated instructions and examples that can assist them to find the solution to mathematical problems that helps in reducing cognitive conflict during learning (Davis, 2000). In conclusion, metacognitive scaffolding helps to support students to process ideas that are related to a problem during learning as well as regulating their cognitive process so that they can understand new ideas (Lee & Hannafin, 2016).

Mathematical tasks that teachers choose and provide to students during teaching acts as a key to support students' conceptual understanding. A mathematical task is whatever a teacher uses to demonstrate mathematical concepts, engage students in interaction, or

request students to do something, such as homework problems and classroom activities individually or in a group. It is through the tasks that teachers can present mathematical concepts and processes that can provide cognitive conflict and through the tasks students can resolve the cognitive conflict. Mathematical tasks, carefully orchestrated, may spark students' curiosity and interest, inform students of what it means to do mathematics, and thus shape their mathematics identity and determine their future progression in related pathways. Therefore, teachers of mathematics should prepare to give students' individual mathematical task (Sayce, 2010). Sayce (2010) also explained that this should be done so that students can think about what has been taught during the lesson. In this, the able learners can easily work alone while those who are unable to consult from others. This time is important because individuals can think deeply and come to a solution on how the problem should be solved. This will motivate the teacher to be attentive towards the lesson as well as help in improving students' understanding that promotes conceptual change (Akpinar et al., 2009).

A teacher should prepare to give learners task or work in pairs so that they can discuss (Sayce, 2010). This should be done according to the needs of the learner. It will help the students who cannot solve a problem to get ideas from other classmates and solve the problem that results from cognitive conflict during the lesson. Cognitive conflict should be the vehicle to be used by the teacher, and other students to correct other learners who have the problem since the students who have misconceptions should be corrected so that they modify their thinking towards scientifically accepted methods (Kang et al., 2010). The teacher has the power to ensure that whole class discussion is done midway to a lesson so that learners can react to their cognitive conflict (Sayce, 2010). It helps the teacher to improve the learners' understanding of the lesson by offering guidance to learners in areas they experienced cognitive conflict. Sayce continues to argue that the teacher needs to prepare learners for cognitive conflict because cognitive conflict is a good way of learning if the problem can be solved. The teacher in this may give learners a problem to solve that can be used to measure their understanding of the topic discussed or may be used to explain concepts in the next lesson (Maharani & Subanji, 2018).

Teachers are also advised to take advantage of cognitive conflict and even to go ahead and create conflict scenarios. The conflict scenarios should make teachers employ a collaborative learning process so that students can possess a better understanding of the concepts as they discuss (Watson, 2007). Cho (2015) illustrates that teacher's preparedness to deal with cognitive conflict in mathematics lessons is evidenced through programmed learning. In this, the teacher helps in schematic structuring of the students by keenly observing them throughout the lesson and identify any occurrence of cognitive conflict in them during the problem solving process (Haataja et al., 2019).

Teacher preparedness to deal with cognitive conflicts in mathematics can also be evidenced by how they respond to students' wrong or incorrect responses during mathematics lessons (Gal, 2019). This requires that the teacher should have Pedagogical Content Knowledge (PCK), Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), Knowledge of Content and Student (KCS), Knowledge of Content and Teaching (KCT) and finally Knowledge of Content and Curriculum (KCC) (O'Brien & Iannone, 2018). Pedagogical Content Knowledge refers to subject-specific knowledge about teaching that includes student difficulties and prior conceptions as well as content-specific instructional and assessment strategies that are used to assess the students' learning outcome. On the other hand Common Content Knowledge refers to in-depth conceptual background knowledge as well as in-depth knowledge of content in the respective domains, for example knowledge in science and mathematics. Also, Specialized Content Knowledge refers to knowledge required to teach mathematics that extends beyond the knowledge to do mathematics. Moreover, Knowledge of Content and Student is defined as the knowledge about the content to be taught and knowing about students. On the other hand, Knowledge of Content and Teaching refers to knowledge that combines knowledge of teaching as well as knowledge of mathematics and finally Knowledge of Content and Curriculum refers to knowledge about essential elements of teacher knowledge. Therefore, the use of cognitive conflict is important to be included in student-teacher preparation and development programs since this strategy will make teachers aware of how their students understand concepts and help them reach a rational decision on how to help students solve mathematical problems during learning situations (Gal, 2019).

2.7 Theoretical Framework

This study was guided by the cognitive dissonance theory since cognitive conflict is characterized by cognitive dissonance (Festinger, 1957). In Festinger's explanation of dissonance theory he stated that cognitions (for instance, bits of information about oneself or the social and physical world) could either be relevant or irrelevant to one another. Because when relevant cognitions are found to be incompatible, the individual will experience cognitive dissonance, defined as a drive-like physiological reaction (similar to hunger), which produces psychological discomfort and motivates the individual to reduce the cognitive conflict (Festinger, 1957). According to this theory, human beings strive to achieve consistency among cognitive elements (such as perceptions, knowledge, and behaviors), and a discrepancy between these elements leads to cognitive conflict, that makes the individual uncomfortable and thus tries to reduce the conflict by altering one of the cognitive elements. Festinger gave the principles of this theory that includes, cognitive conflict that emerges when an individual must choose between attitudes and behaviors that are contradicting, and it can be eliminated by reducing the importance of the conflicting beliefs that change the balance or by removing the conflicting behavior and attitude (Harmon-Jones & Mills, 1999). This helps in knowledge transfer because the conflict state encourages an individual to perform tasks required to reduce the conflict. Cognitive conflict when experienced by students during teaching and learning help in knowledge transfer as students who experienced the phenomenon will be able to develop more interest on how different mathematical problems can be solved (Sayce, 2010).

In this research, this theory was preferred because it is relevant to decision making and problem solving situations that this study made use of. In this theory Festinger (1957) also gave ways on how cognitive conflict can be reduced in any situation. He explained that cognitive conflict can be eliminated by reducing the importance of the conflicting belief for example by gaining adequate knowledge on how to solve different mathematical problems critically. Cognitive conflict can also be reduced by adding more constant beliefs that reduce the conflict belief and finally changing the conflict belief so that it is no longer inconsistent (Harmon-Jones & Mills, 1999). Festinger (1957) presents that cognitive conflict moment is motivational because it requires one to identify an appropriate strategy

to reduce the conflict situation. In this theory, Festinger argues that cognitive conflict can as well be a psychological discomfort to an individual. The discomfort state is significant as it makes learners have an interest in how they can solve mathematical problems. According to Festinger, arousal and discomfort are the conflict reduction strategies that teachers of mathematics should make use of during mathematics teaching and learning to reduce the cognitive conflict to students.

2.8 The Conceptual Framework

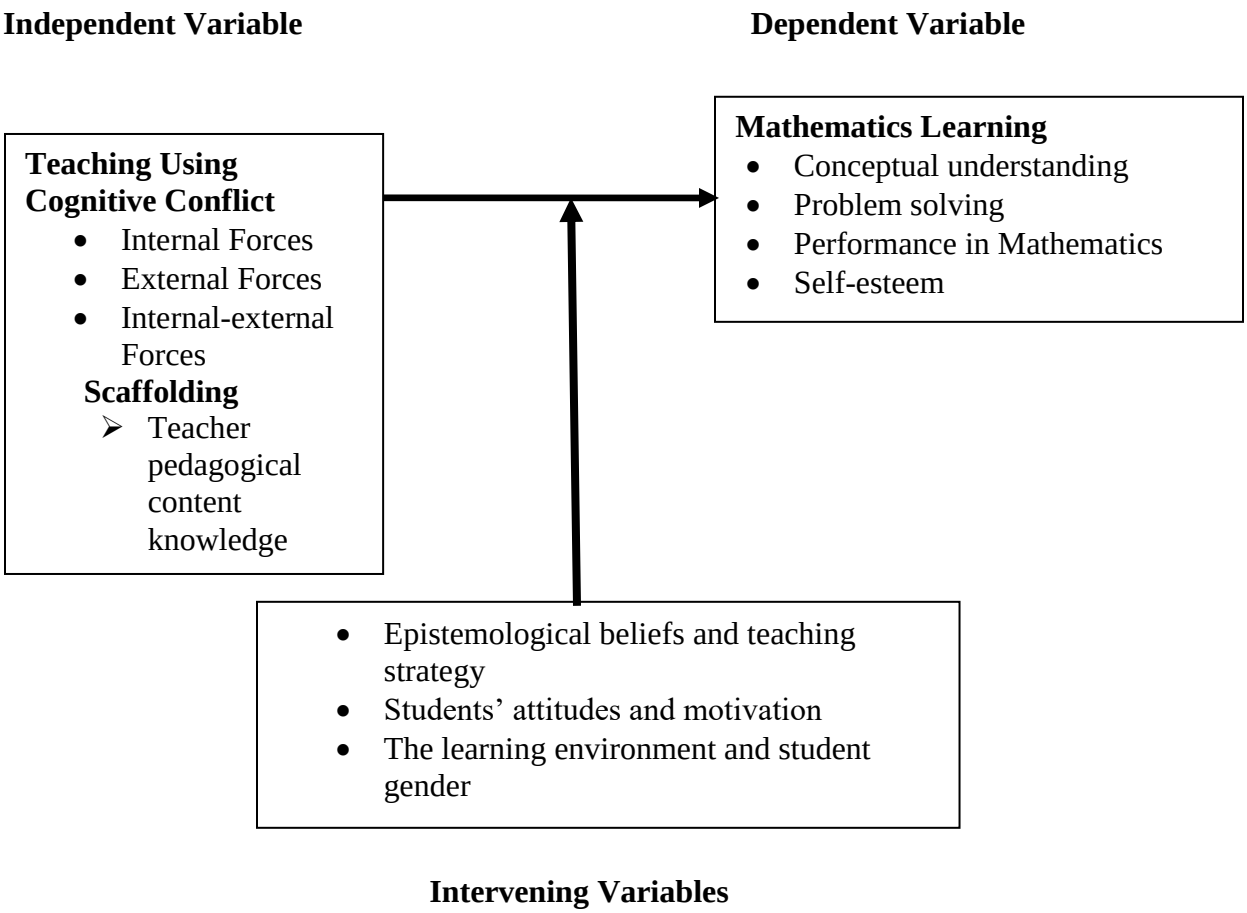

Figure 2.1: Conceptual Framework about the Study Variables

From Figure 2.1, teachers' perception by teaching using cognitive conflict is the independent variable, while students' perception to gain knowledge through mathematics learning is the dependent variable. As noted above, cognitive conflict can be categorized as either internal forces, external forces, or internal-external forces. Also, teaching using

cognitive conflict involves scaffolding that depends on teacher pedagogical content knowledge. On the other hand, indicators of mathematics learning include students' conceptual understanding, students' problem solving strategies, performance in mathematics, and students' self-esteem.

The relationship between cognitive conflict and mathematics teaching and learning is influenced by such intervening variables as teachers' and students' epistemological beliefs, students' attitudes, and motivation. Thus, for example, if there are poor epistemological beliefs and teaching strategies, then the quality of mathematics teaching and learning will be poor and vice versa. Rephrased otherwise, if the teachers are not adequately prepared to support the students overcome their cognitive conflict, then the students' quality of learning in mathematics will be low and vice versa.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the research design as well as the location of the study. It also considers the target population and sampling techniques. It explains about sample size, research instruments, and how the pilot study was done. It captures validity and reliability as well as data collection techniques. The chapter concludes by giving details about how the data collected were analyzed as well as logistical and ethical considerations that guided the study.

3.2 Research Design

This study adopted a mixed method research design as it helped in organizing the research data as well as in viewing the phenomenon under study as a whole. In particular, the study employed exploratory sequential mixed methods design by explaining in details the qualitative findings from the participants that were then used to build quantitative data to provide comprehensive analysis about phenomenon under investigation (Creswell, 2014). The design enabled the researcher to obtain information on the utilization of cognitive conflict as a teaching-learning strategy to assist teachers, policymakers, and educators on how students' learning can be improved based on cognitive conflict.

3.3 Location of Study

The study was conducted in public secondary schools in Embu West Sub-County in Embu County-Kenya. Embu County is one of the forty-seven counties in Kenya where each County has two types of secondary schools namely; private and public schools. The public secondary schools are further categorized into National, Extra County, County, and Sub-County schools based on students' performance and teaching-learning resources available. The education system in secondary schools in Kenya is based on four grades, termed as Forms (Form 1, 2, 3, and 4). The choice to research in this Sub-County had been

purposively made by the researcher because of its poor performance in mathematics in the national examination that had been highlighted by researchers from this county (Kivuti, 2015; Njagi, 2013). This study was thus addressing a felt need for a study to be done in Embu West Sub-County on ways that can promote mathematics learning so that the quality of academic outcome can be improved (Njagi, 2013). The sub-county has a total of 25 public secondary schools out of which 6 are single-sex boarding schools and 19 are mixed-sex day secondary schools.

3.4 Target Population

The study targeted all the 25 public secondary schools in Embu West Sub-County. This target population had 2800 Form Two students and 48 Form Two teachers of mathematics as shown in Table 3.1 below.

Table 3.1: Sampling Framework Showing Number of Public Schools, Population of Students and Teachers

School type	No. of schools	No. of students	No. of teachers
Boys' boarding	3	888	14
Girls' boarding	3	602	10
Mixed day	19	1310	24
Total	25	2800	48

Source: Embu West Sub-County Education Office

Form Two students aged between 15 and 16 years were purposively selected because it is a critical stage in secondary school mathematics in Kenya, where students need to be supported as they develop critical thinking and problem solving skills. It is also the stage at which new mathematical concepts are introduced following the transition from primary school mathematics. The students were purposively selected based on their performance in recent mathematics examination, whereby the top performers were selected since they were found to possess an interest in mathematics and thus their participation was considered

crucial in answering the research questions for the study. This is because students who enjoy mathematics always make use of deeper learning strategies, which results in better grades (Pekrun, 2006). Form Two mathematics teachers participated in the study since the study focused on Form Two class where they are expected to do many roles in the classroom during teaching like building a healthy and active environment, act as a counsellor and support students by handling cognitive conflict to ensure students' conceptual understanding.

3.5 Sampling Techniques

The study used purposive sampling to select the sub-county and the participants for the study, since the method can be used to select the study area and participants of particular characteristics of the population that can give the best responses about the research questions in the study (Creswell, 2013). A census of all 25 public secondary schools in Embu West Sub-County was conducted. The study made use of stratified sampling for representation from all subgroups. Based on this, the public secondary schools were divided into strata according to particular characteristics shared by the schools namely; school culture which contains strategies set and followed within a school with an aim of improving students' performance. Also, human and teaching resources that are useful in upgrading classroom teaching towards better academic achievement. Specifically, the schools were categorized into three groups; namely boys-only boarding schools, girls-only boarding schools, and co-educational schools. To get participants for the study, the researcher purposively selected students based on their performance in recent mathematics examination results. This is because students who enjoy mathematics always make use of deeper learning strategies, which results in better grades (Pekrun, 2006). From the result only top students in the list were picked since they were found to possess an interest in mathematics and thus their participation was considered crucial in answering the research questions for the study.

3.6 Sample Size

As noted above, the study was conducted in all the 25 public secondary schools in Embu West Sub-County. The sample size for the student participants from these schools was determined using the Yamane model to arrive at a sample of 350 Form Two students (Yamane, 1967). Mathematical illustration for Yamane model used is as follows:

$$n = \frac{N}{1 + N\,e^2}.$$

In the equation above, n is the sample size, N is the population under the study, and e signifies the margin error (0.05).

Teachers of mathematics in Form Two in the school were recruited for the study and the number of students and teachers per each school category is shown in Table 3.2 below.

Table 3.2: Showing the Distribution of School type, their Number and the Number of Sampled Students and Teachers

School type	No. of schools	No. of students	No. of teachers
Boys' boarding	3	111	14
Girls' boarding	3	75	10
Mixed day	19	164	24
Total	25	350	48

To get the exact number of Form Two students to participate in the study per school, the researcher calculated this value depending on the number of Forms Two students in the school relative to the total using the formula in the next page.

Number of students participant per school $= \frac{k}{2800} \times 350$.

In this equation, k is equivalent to total number of Form Two students in the school, 350 is the sample size and finally 2800 is the target population. For instance, if the total number

of Form Two students in a given school was 232 then only 29 students were selected. Also, if the total number of Form Two students in another school was 50, then only 6 students were selected. At least 4 students were engaged in a semi-structured interview from each school until the point where the researcher attained data saturation. This is because, there is no specific number of interviews needed for a qualitative study to reach data saturation that could give the specific number of schools to be sampled (Bernard, 2012).

3.7 Data Collection Techniques

The study used semi-structured interviews and surveys to collect information from the respondents. These methods helped to get qualitative and quantitative information from Form Two students and Form Two teachers of mathematics about the cognitive conflict in mathematics learning (Creswell, 2014). Moreover, during the study cognitive conflict was explained to participants as a moment in mathematics learning when a student or a teacher solved a mathematical problem using a method that was different from the one they expected them to use. Four students from each of the sampled schools were each engaged in the one-on-one semi-structured interview until the point where the researcher attained data saturation. In total 68 students (32 females and 36 males) drawn from 17 secondary schools (6 single-sex and 11 mixed-sex) participated in the interviews. The interviews were conducted in a quiet place within the school compound. For example, some interviews took place inside the school laboratory.

During the study, the researcher interviewed the selected students and recorded their opinions about cognitive conflict after they had filled the questionnaires. Interviews were appropriate for this study as the information obtained provided in-depth understanding of cognitive conflict from participants' arguments. It also assisted the researcher to identify data saturation point because at this point any information or themes observed from the students was not adding any new information or themes to the previous data collected about the study (Bernard, 2012). The interviews were 20 to 30 minutes long and were audio-recorded. To begin the interview, the first interview question was requesting participants to rate their ability by stating the percentage they think they can score in KCSE results in mathematics. The rest of the questions were about the manifestations of cognitive conflict

by students in mathematics learning. Also, some items were exploring the strategies employed by teachers and students to react to the situation in mathematics learning. After collecting the required information from participants, the researcher organized the information collected using these methods for data analysis.

3.8 Research Instruments

The study used an interview to get learners' manifestations about the cognitive conflict in mathematics teaching and learning during the one-on-one semi-structured interview. The interview is appropriate in getting in-depth understanding of the students' challenges during mathematics teaching and learning (Pratiwi et al., 2019). The interview guide that was used to achieve the information that answered objective one of this study is shown in the appendix section. Questionnaires were also used to achieve the second and third objectives. Questionnaires give more information that is accurate and from a large number of people (Creswell, 2014). The questionnaires had open and close-ended questions that Form Two students and Form Two teachers of mathematics answered.

The closed type of questions used the form of a Likert scale known as cognitive conflict level test (Lee et al., 2003). In this scale the participants were required to give their responses on a 5-point Likert scale ranging from 1= Strongly Agree to 5= Strongly Disagree. To address cognitive conflict, there were 12 items in the teacher's questionnaire and 16 items in the student's questionnaire. Objective two had 9 items on the student's questionnaire and 6 items on the teacher's questionnaire. The third research question of this study was answered by open and closed-ended questions in the students' and teachers' questionnaire. For closed, there were 13 items in the teacher's questionnaire and 14 items in the student's questionnaire. Moreover, the questionnaire containing the items stated above is shown in the appendix section. The researcher self-administered the questionnaire to the respondents of the schools.

3.9 Pilot Study

A pilot study was done for validation and testing the reliability of research instruments that were used to conduct the study in order to test whether the research instruments were

working (Kombo & Tromp, 2006). The instruments were piloted in one randomly selected secondary school. This was to ensure that each school regardless of category or type had an equal chance of being selected to participate in the study. The piloted school was not included in the main study. Piloting helped the researcher with experiences on how to use the instruments as well as enables him to conduct practice interviews with students to understand the right questions to ask during the actual study (Mulungye et al., 2016). Also, it helped the researcher to identify any problem with the instruments and design to be used for the study. The data collected at this stage were useful in the modification of the instruments so that they could yield valuable data needed about the study.

3.10 Validity of the Instruments

Validity is the degree to which a test measures what it is supposed to measure (Creswell, 2014). A research instrument is valid if the content it contains is relevant to the study objectives (Adino, 2015). The study adopted content validity where the tested items represented the content that the test was designed to measure. The content of the test in this study was prepared by synthesizing relevant information from different articles available online about the cognitive conflict and students' mathematics learning by the researcher in consultation with the supervisors.

3.11 Reliability of the Instruments

Reliability refers to the replicability of the instruments to yield the same results over several repeated trials (Kombo & Tromp, 2006). The study used a test-retest method of assessing reliability, whereby the questionnaires were administered twice after a week to the same group of individuals to test for the reliability of the results. The correlation coefficient was calculated to find out whether the instruments yielded data that had a high test-retest reliability about the study. Therefore, the result from the piloted instruments showed that Cronbach's Alpha was 0.74 for the instruments which were used to get information to support this study. This result indicated that the instruments were valid and reliable to get adequate information to support the study.

3.12 Data Analysis

Qualitative data obtained from the interviews and the questionnaires were analyzed by first transcribing, followed by developing codes, and finally organizing codes into themes (Creswell, 2014). The study made use of thematic analysis whereby the transcriptions were analyzed by first reading the whole text followed by re-reading and developing codes of the transcriptions. The codes were written along the margin of the document using keywords from participants' responses. The developed codes were then organized into larger categories and finally, the categories were organized into three overarching themes that are now presented in the subsequent sections (Terry et al., 2017). Examples on how themes were arrived at is shown in appendix I in the appendix section. Quantitative data were analyzed using the Statistical Package for Social Sciences (SPSS) for descriptive and inferential statistics. For inferential statistics, the researcher used a t-test to test whether there were significant differences between male and female students' approaches to cognitive conflict which answered research question two of the study.

For descriptive statistics, the researcher used the mean, mode, median, standard deviation, and frequencies of the responses from the questionnaires to describe the quantitative data to answer objective three of the study. Also, the findings are represented using tables, graphs, and charts. The responses from the 5 points Likert scale in the teachers' and students' questionnaires ranging from strongly agree and agree were presented as agree while not sure, disagree, and strongly disagree were rated as disagree for analysis of the participants' responses (Subedi, 2016). Also, based on the information that was obtained from the respondents in the questionnaires, the researcher made inferences about the use of cognitive conflict by teachers of mathematics to scaffold students' mathematics learning in public secondary schools in Embu West-Sub County.

3.13 Logistical and Ethical Considerations

This research was approved by the Board of Postgraduate Studies at the University of Embu. The study was also authorized by the National Commission of Science, Technology, and Innovation (NACOSTI) from the Ministry of Education, Science and Technology (MOEST). A permit to carry out the study in Embu West Sub-County was issued by

County Director of Education in Embu as well as the Sub-County Director of Education in Embu West. Individual school site permission was granted by the school principals, while informed consent was obtained from each of the teacher and student participants. The researcher made arrangements to visit the schools before the study to familiarize with the school, to build rapport with the research participants, and to explain to them the purpose of the study as well as arranging the day and time to conduct the study. The researcher acknowledged any reference made on other researchers and scholarly works. Also, this study ensured confidentiality by requesting the respondents to omit their names from the questionnaires. The respondents were also assured that the information given was strictly confidential and to be used only for study purposes. This study ensured that no reference is made to individuals or schools that participated.

CHAPTER FOUR

PRESENTATIONS OF FINDINGS, INTERPRETATION, AND DISCUSSIONS

4.1 Introduction

This chapter presents the research findings and their interpretation based on the analysis of the data collected for the study. The chapter also presents the discussion of results in line with the study objectives.

4.2 Demographic Information of the Study Participants

As mentioned earlier participants for the study were Form Two students and their mathematics teachers. The Figure 4.1 below shows the distribution of students who participated in the study by gender.

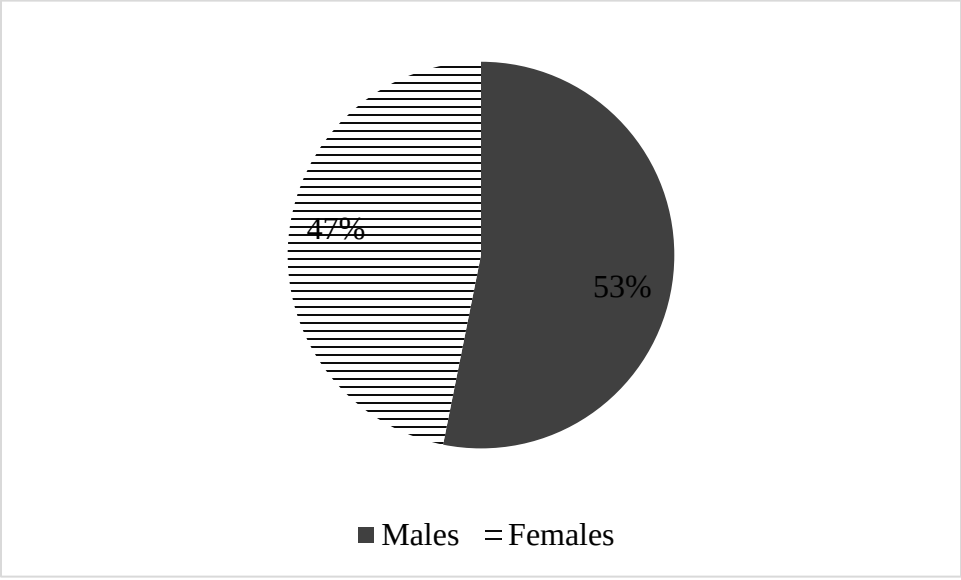

Figure 4.1: Composition of Students' Gender

From Figure 4.1 above, 53% of the students who participated in the study were males while 47% were females. Therefore, there were more male than female students in this study. The students were also categorized by the type of schools they were drawn from as shown in the Figure 4.2 in the next page.

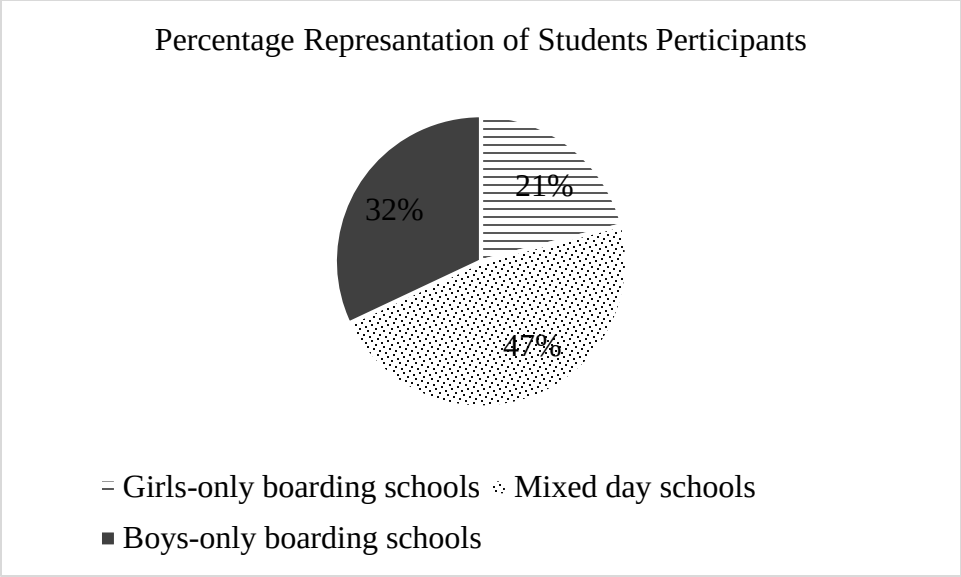

Figure 4.2: Percentage Representation of Students per School Categories

From Figure 4.2 above, the majority of the students that is 53% were from single-sex secondary schools, while a minority (47%) were from co-educational day schools. Moreover, the distribution of teacher participants by gender is as shown in Figure 4.3 below.

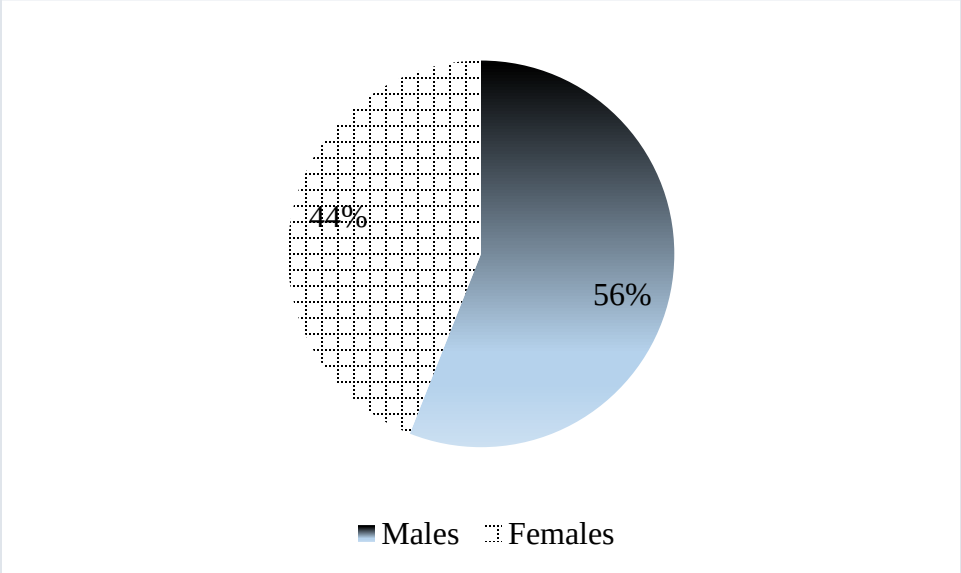

Figure 4.3: Composition of Teachers' Gender

From Figure 4.3, 56% of teachers who participated were males while 44% were females. Furthermore, 21% of these teachers were from girls-only boarding schools 50% were from co-educational secondary schools, while 29% of them were from boys-only boarding schools.

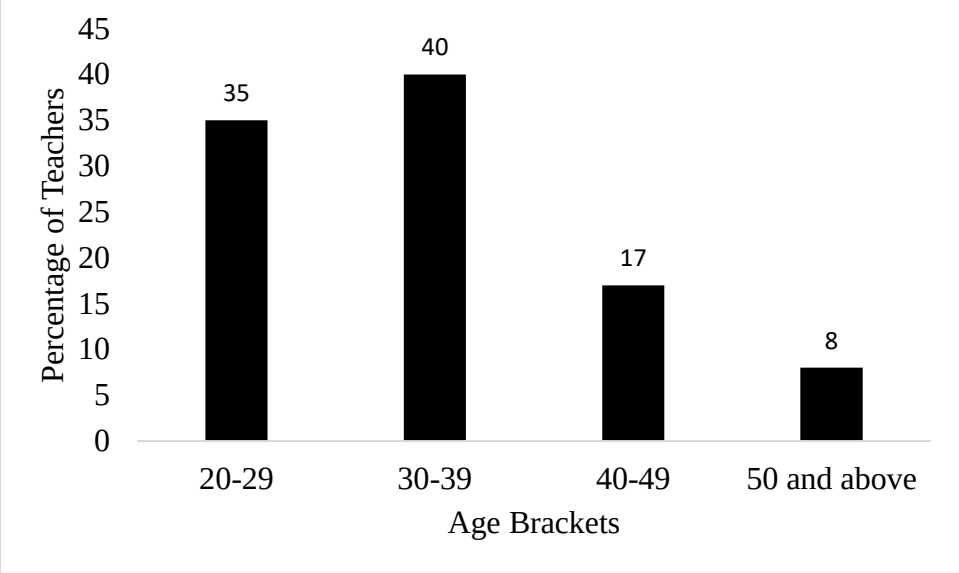

Figure 4.4: Distribution of Teachers' by Age

Figure 4.4 shows the distribution of teachers who participated in the study by age. From the figure, the majority of the teacher participants (75%) were aged between 20-39 years while a minority (25%) were aged 40 years and above.

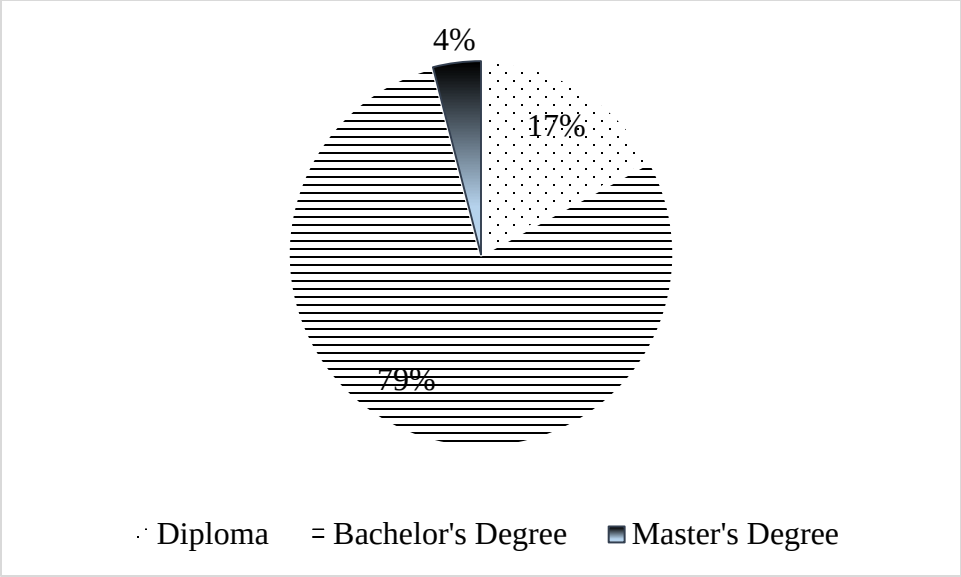

Figure 4.5: Percentage Representation of Teachers' Based on Academic Qualifications

The study found that based on teacher's academic qualifications as indicated in Figure 4.5 above, the majority of the teachers (79%) were bachelor's degree holders. Generally, this study found that the teachers had required academic qualifications for them to teach mathematics in secondary schools.

Table 4.1: Years of Teaching Experience for the Teacher-participants

Teaching Duration in Years	Percentage
1 - 4	44
5 - 10	21
11 - 15	10
Above 15	25

The study obtained information about teaching duration in years a teacher has been teaching mathematics. The findings from Table 4.1, shows that a minority of teachers (44%) had been teaching for a period of between 1 to 4 years, while the majority (56%) had been teaching mathematics for at least 5 years and above. Therefore, this implies that the teachers had a long duration of teaching experience that can help them gain skills on how mathematics teaching can be planned based on cognitive conflict. Moreover, this

study was also interested in finding out whether these teachers had attended any in-service training in the past three years of their service as teachers of mathematics. The result obtained about this is shown in the Figure 4.6 below.

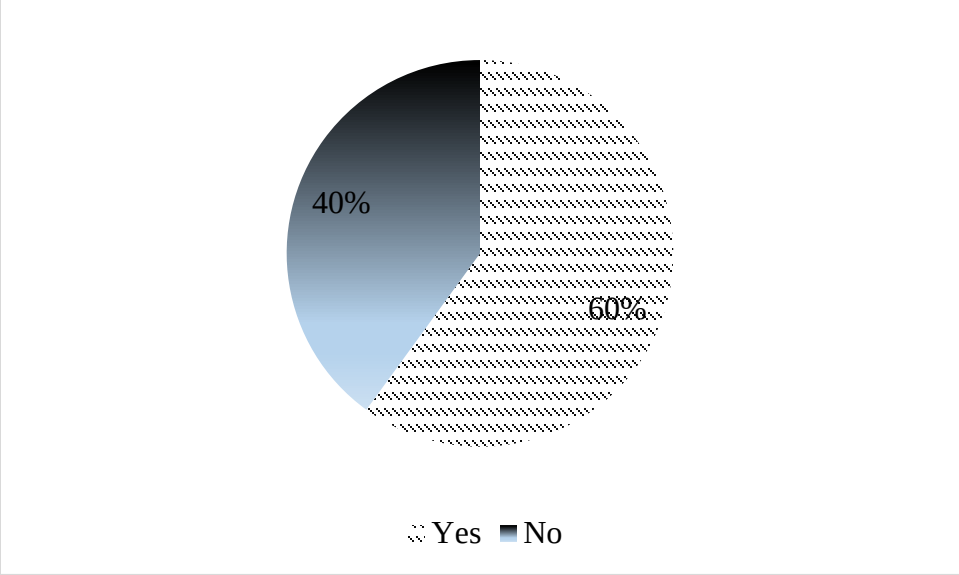

Figure 4.6: Teachers Attendance to In-service Training in the Past three Years

From the Figure 4.6 above, 60% of teachers who participated in this study indicated that they had attended in-service training in the past 3 years of their service as mathematics teachers. Therefore, their opinions about the study content will be valuable since some explained that their training was related to supporting students' learning through cognitive conflict. The study was also investigating the number of lessons these teachers were teaching every week. The findings on this are as shown in the Figure 4.7 in the next page.

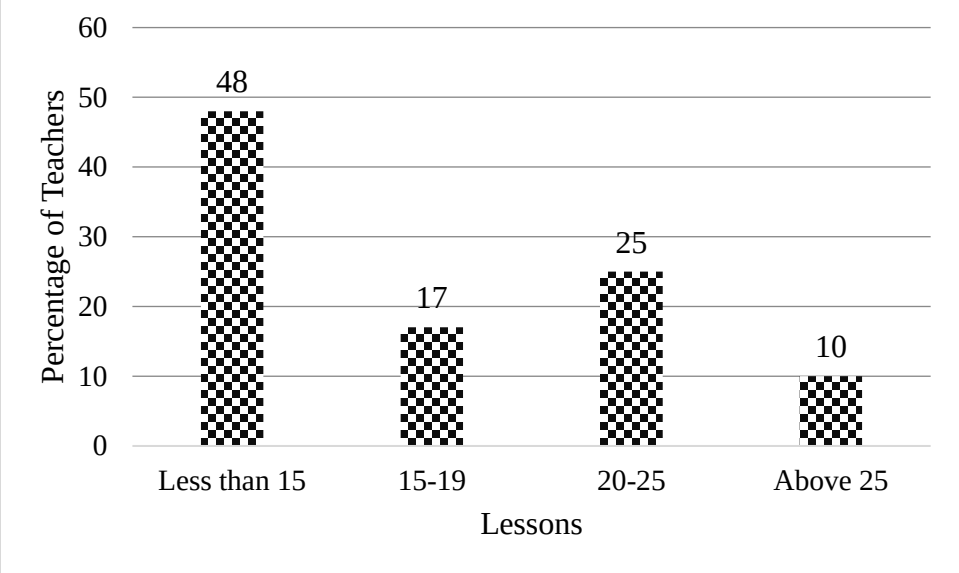

Figure 4.7: Number of Mathematics Lessons Taught Weekly

From Figure 4.7 above, the majority of teachers (52%) taught at least 15 lessons per week, which translates to an average of at least 3 lessons per day. This can make teachers engage in innovative pedagogies for better conceptual understanding by students during mathematics learning. In addition, the minority (48%) of teachers taught at least 1 lesson per day. Thus these teachers can not only engage in innovative teaching strategies for better conceptual understanding by students but also assist their colleagues who have more workload in mathematics to ensure team teaching.

4.3 How Cognitive Conflict is Manifested in Mathematics

From the qualitative information obtained from participants about how cognitive conflict is manifested in mathematics, the data analysis gave rise to three overarching themes; namely, a moment to (co)construct one's mathematical meaning, confusion as a result of a teacher's behaviorist stance, and a fleeting moment of magic.

4.3.1 A moment to (Co)construct One's Mathematical Meaning

From students' opinions, the study found that they experienced cognitive conflict as an opportunity to (co)construct their mathematical knowledge by engaging in group work so that they can get a better conceptual understanding of contradicting concepts. On the other

hand, some students also perceived that cognitive conflict act as an opportunity to individually construct skills on how to solve mathematical problems by consulting reference materials as well as teachers and peers. During the interviews, some students explained that as they consult their teachers they always find solutions to ideas that contradict their skills during mathematics learning. The study also found that students do appreciate teachers' methods as the best once they get to know how to utilize them in problem solving. During the interview, a male student said:

> By consulting the teacher, I felt very good because I was introduced to many ideas of solving Simultaneous Equations, unlike the previous situation where I had only one way to go. Also, you know that teachers are different and I found it good because if they can come up with their ideas and I also come up with mine I then get mathematics easy (Informant. 67, 2020).

The student explained that he feels good by sharing his experiences about a concept with the teacher. Moreover, as explained by him, sharing ideas with the teachers helped him to gain more skills on how the concept can be solved that helps in solving the new concepts that contradict his lived ideas. Also, some students only prefer consulting their peers as a result of the difficulty and fear to consult their teachers. During the study, some students argued that they got introduced to some topics in Form Two and found difficulties to understand them because the contents in that topic were a continuation of a given topic they were not introduced to in Form One. Under this situation, they stated that they sought assistance from their peers who understood the concepts either by consulting reference materials like books. During the interview, a student said:

> In Form One there are some topics we were not introduced and now we have them in Form Two. These topics, for example, the Simultaneous Equations I came to understand this topic just another day when I consulted a friend, but anytime I consulted a teacher to be clear I was getting nothing (Informant. 33, 2020).

The student argued that the reason to seek help from the peers as opposed to his teacher was due to difficulty in understanding the teacher’s concept explanation. Besides, this study's findings have confirmed the findings by Sayce (2010) who argued that low self-esteem, stuck moments where students are unable to understand and follow what the

teacher is explaining during teaching are a manifestation of cognitive conflict by students. During the study, a student argued as follows:

> I just feel low because I may see I am in class, the teacher is teaching and I feel just low because I am unable to understand due to confusion, but at last, I must find help from the students who got the concept from the teacher and finally solve the problem (Informant. 3, 2020).

Students explained that they can react to cognitive conflict by using reference materials available so as to get more skills on how to respond to contradicting concepts. However, during the interviews, students argued that as they revise they got confused with some concepts from the reference materials. Moreover, students explained that as they read ahead of the teacher they experienced cognitive conflict as a result of connecting the method learned from the books and the one that the teacher presents during mathematics lessons. Consequently, the students stated that they try to go back and simplify their well-informed method in relation to the one explained by the teacher for better conceptual understanding. In conclusion, during this study, one of the students argued that by going back and reconciling the methods they reduce cognitive conflict by adopting a simpler method that they can all understand and use for problem solving. He said:

> Some of us we read ahead of the teacher and you find that if you read ahead of the teacher, the teacher might come with a different formula but the answer is the same, but under that condition, we try to adopt a shorter method so that we can all understand it and use to overcome confusion (Informant. 67, 2020).

As a result of feedback from students, therefore, the study proposed that teachers should employ cooperative learning by ensuring that students work in groups. In this, teachers are supposed to prepare tasks to students that provoke critical thinking so that as students discuss they get to learn more of the concepts. On the other hand, teacher educators should enhance student teachers with skills in group work so that they can group students based on their abilities to promote productive work among the groups.

4.3.2 Confusion as a Result of Teacher's Behaviorist Stance

As reported by Pange et al. (2010) that behaviorists view learners as passive individuals and hence teachers who used this approach teach from a teacher-centered approach.

Considering students' opinions, this study found that the teachers embraced behaviorism in teaching mathematical concepts by not considering students' methods. This is because students explained that teachers failed to articulate their ways of solving different mathematical problems during teaching. This is due to the fact that teacher's instruction on the method to be employed by students to solve some mathematical problems was reported by some students as a factor that results in their confusion in mathematics. Consequently, students explained that as a result of the teacher's behaviorist stance, they found it difficult to understand the teacher's methods and felt confused when instructed to use such methods in problem solving. During the interview, a student said:

> Some areas like I try what I can but due to instructions on the method to be used by the teacher to solve the problem, I try to follow but I can't see anything (Informant. 37, 2020).

The student explained that he experienced confusion due to the teacher's instruction on the method to be employed in problem solving. Some students also explained that they experience difficulties as they proceed with solving mathematical problems while employing the teacher's prescribed methods. This was explained by students as a problem in *Ratio and Proportions*. The manifestation of cognitive conflict from students' perspective in this area was as a result of the teacher's insistence on the method he had taught and instructed students to use. Students explained that in applying the new method, there is a point they are required to look for a smaller fraction that needs them to apply the skills taught, and in the process they get confused. During the interview, one student explained that:

> The teacher insisted that I should stop using my primary method and use the one he has taught that needs me to hide and search for a smaller value and multiply that with the other. In the process of using the teacher's method, I get confused and get stuck on what I should do next (Informant. 38, 2020).

During the interview, some students claimed that they experienced difficulties in understanding and applying the prime factorization method (Box 1) that most of their mathematics teachers instructed them to use as opposed to the long division method (Box 2) in finding square roots of numbers.

- **Step 1**: Divide the number given to its perfect square factors.
- **Step 2**: Take the square roots of the perfect square factors and multiply to get the square root of the number given.

Box 1: Prime Factorization Method for Finding Square Roots

During the interview, one of the students used the method in Box 1 to determine the square root of 225 as follows:

$$\sqrt{225} = \sqrt{(25) \times (9)}$$

$$= (5) \times (3) = 15.$$

The student argued that while applying the above method in secondary school, he always experienced difficulties at the beginning to find perfect square factors of the number given especially when dealing with big numbers. He said:

> When I came to secondary school the teacher taught and say that we must use this method (referring to the method in Box 1). I found difficulties in this method because I have to first think of the perfect square factors of the number given. This makes it complicated to me because some questions have big numbers and I find difficulties in applying this teacher's method in finding square roots (Informant. 44, 2020).

The difficulty in applying this method by the student in secondary school made him prefer the application of the long division method of finding square roots of numbers that he was used to from his primary school (Box 2) shown below. The student demonstrated his workings using the method in Box 2 in solving the same problem of finding square root for 225 as shown in the next page:

		1	5	
	1	2	2	5
		1		
2	5	1	2	5
	5	1	2	5
				0

- **Step 1**: Separate the digits of the number its square root is to be calculated in pairs or until the point where only an integer is remaining from left. Draw a vertical line to the left of the numbers downwards and a horizontal line on top of the numbers leaving a larger lower section to perform calculations.
- **Step 2**: Find the largest integer n whose square is lesser than or equal to the leftmost number or pair. Divide and write (quotient) n in the top right space and the square of n in the bottom right quadrant respectively. Subtract the square from the chunk analyzed and write the answer underneath.
- **Step 3**: To the right side of the remainder, drop down the next pair. Double the quotient obtained in Step 2 to get (p), then write the p-value in the bottom left quadrant and draw two vertical boxes next to it for a multiplication problem you will do by repeating Step 2 to obtain k, where k is the largest digit for the unit place of the divisor such that the multiplication of the new number pk × k = m, where m should be lower than or equal to dividend from the right.
- **Step 4**: Write k as the second integer, then nk is the square root if the digit number had two pairs. Moreover, if the number for which the square root is sought can be grouped into 3, 4, or 5 pairs, then the square roots will also have 3, 4, 5 digits, respectively. Therefore, the number to double before drawing two boxes depends on the pairs of the digit number its square root is sought and it differs after each iteration until the point where the last pair is dropped.

Box 2: Long Division Method of Finding Square Roots

In his description of the discrepancy in employing the new method in secondary school, the student claimed that he experienced more cognitive conflict in finding square roots of

numbers that are perfect square and have big values. Under this situation, therefore, the student explained that he employ both methods to confirm the answers to different square roots. Due to this, the study suggests the value of cognitive conflict in mathematics teaching and learning as a situation that can assist students to develop a better conceptual understanding of how different mathematical concepts can be applied (Sayce, 2010; Susilawati et al., 2017). The difficulty in applying the teachers' methods made students experience mixed feelings, with some students feeling as if the teacher was showing them the wrong thing. Generally, the majority of the students claimed that the teacher's prescribed methods in problem solving during teaching made them feel confused, discouraged, and have negative feelings towards mathematics. For example, one student said:

> I feel bad and confused because the sum which the teacher gives a different way from the one I am used to and the teacher stressed that I must use the method taught and I can't use the teacher's method, by the time I realize that I have failed the question I feel more disappointed (Informant. 68, 2020).

This clearly indicates that a teacher's behaviorist stance can discourage students' from finding diverse ideas on how different mathematical problems are solved, thereby hindering their conceptual understanding. It is therefore important for teachers to value students' ideas, opinions, and preferences during the teaching process by adopting constructivist approach (Graffam, 2003; Vosniadou & Verschaffel, 2004). This will aid in transforming cognitive conflict moments into learning moments because students will be encouraged to develop more interest in the lesson topic of discussion as well as in understanding concepts for which they experience cognitive conflict. Therefore, the study emphasizes that teachers should be trained on appropriate cognitive teaching strategies they can use to teach topics that students are likely to have a way and a belief in how problems are solved. This is because the study has found that students have experience with much of the content covered at lower levels in secondary school from their primary school knowledge but in secondary school, the concepts are the same but only with some variations. Also, teachers should adopt appropriate teaching strategies that aim at supporting students to overcome challenges due to cognitive conflict in mathematics learning towards obtaining good grades in the subject. Therefore, this study encourages

teacher educators to prepare teachers based on the challenges they are likely to face when they meet high school students, especially at the lower levels.

4.3.3 A Fleeting Moment of Magic

From the interpretation of students' narratives guided by the thematic analysis, the study found that students' experienced cognitive conflict as a fleeting moment of magic as a result of how new strategies of problem solving were introduced to them by the teachers during mathematics learning. The students interviewed perceived that their teachers always make mathematics concepts appear abstract based on how they do explain them. The challenge is that teachers view fast concept explanation as a strategy for developing problem solving skills in students. However, the students communicated that they were uncomfortable with this approach by arguing that the situation did not help them accommodate and use the gained skills to reduce their challenges with comprehension of concepts in mathematics. In addition, the students explained that their teachers need to resonate the concepts with their experiences for better understanding. A male participant said:

> The method is there the teacher has guided me but if I come to calculate the area I find difficulties because without capturing the teacher's method which is different from mine, and it was explained faster, I find it is stressful (Informant. 3, 2020).

This student attributed his experiencing of cognitive conflict to the teacher's hasty explanation of the concepts. The study also found that students are interested in making use of their teacher's skills to solve mathematical problems. The challenge, however, is that they found it difficult to adapt to their teacher's magic concept explanations. During the interviews, a student claimed that:

> The moment I try to capture what the teacher has done, I realized that the teacher has gone to the next step before I understand the first step (Informant. 9, 2020).

As evidence by the above student's encode, the majority of the students interviewed expressed the need for a step by step concept explanation by teachers to facilitate their understanding of the concepts and thereby aid in resolving cognitive conflict. The students

further advocated for teachers to employ contextualization during teaching so that students can develop conceptual understanding. One of the student said:

> The teacher should explain concepts step by step so that I can understand the ideas well without getting stuck on the way (Informant. 30, 2020).

Teachers who move fast while explaining mathematical concepts without considering students' experiences sometimes omit important steps that students could utilize in problem solving. At many times, this omission failed to recognize that students had their own way of solving different mathematical problems. For instance, one of the students experienced cognitive conflict simply because the student had her own way of solving the problem, which was different from the one the teacher used. During the interview, the student shared a mathematical problem in *Commercial Arithmetic* whose solution during her primary school days differs from the solution in secondary school. The question was formed as follows, calculate the profit received by a farmer if he sold his farm products for about KShs 1,800 at a 20% profit? The student explained that her primary school mathematics teacher told them that in solving such a problem, they should start by evaluating the value that is equivalent to 100%.

During the interview, the student started by equating KShs 1,800=100%, and asked herself like, what will be the value of 120%? She explained that using her primary school knowing the answer to the question can be calculated as follows:

$$profit = 120\%, 1{,}800 = 100\%,$$

$$120\% = ?$$

$$\frac{1{,}800 \times 120}{100} = 2{,}160,$$

$$profit = (120 - 100)\%,$$

$$= KShs\ (2{,}160 - 1{,}800),$$

$$= KShs\ 360.$$

From the student calculations above, it is clear that she can apply her primary school knowledge in solving profit for the question. As she proceeded to secondary school, the

student explained that to solve the same problem her secondary school mathematics teacher started by saying that you find 20% of KShs1, 800 as shown below.

$$\frac{20}{100} \times 1800 = 360.$$

The student revealed that as a result of the teacher's abstract concept explanation above, she experienced confusion in understanding the new method and failed to know what was happening during the lesson. Step by step concept explanation is appreciated by every student because the presentation of mathematical problems to students as abstract make students to experience cognitive conflict as well as gaining limited knowledge about the concept. During the interview, Jack indicated that due to the teacher's hasty concept explanation he was unable to understand the method that the teacher introduced during the lesson and sought assistance from his friend on how to solve the problem. He said:

> The teacher solves it in another way which I was unable to understand because he was moving fast. As a result of failing to understand, another fellow told me that he had a different way of solving that problem and he showed me and I decided to follow that way (Informant. 39, 2020).

The problem that Jack explained was about the topic of *Indices and Logarithms*. From Jack's presentation during the interview, it came out clear that he had a conflict with how the problem should be arranged even after getting the idea from a friend. This shows that cognitive conflict makes students seek help from their friends and in the process they sometimes fail to understand the application of the theory wholistically. The problem was: without using the logarithm table, solve $\log 72$ given that $\log 2 = 0.1234$, and, $\log 3 = 0.5078$. Jack explained that by solving the problem he was used to first find the factorization of the number given. For example, in this case, the number is 72. So his procedure was as follows:

$$72 = 2 \times 2 \times 2 \times 3 \times 3$$

$$= 2^3 \times 3^2$$

After solving the problem as shown above, Jack continues to describe that because the value for $\log 2 = 0.1234$, and that of $\log 3 = 0.5078$, then he just pick the first exponential

2^3 and take the exponent (3) and multiply with what the value for $\log 2$ is equated to and proceeded with the same procedure for that of $\log 3$, as follows.

$$0.1234 \times 3 = 0.3702$$

Jack continued by solving and explaining as follows:

$$0.5078 \times 2 = 1.0156$$

Then Jack gave out the solution as ($\log 72 = 0.3702 + 1.0156$). Therefore, by using his method he obtained the final answer as,($\log 72 = 1.3858$). Jack explained as follows:

> I just find the prime factorization of this $log72$ like told that $log2 =$ a given number, $log3$ is also equal to a given number, then I asked myself what about, $log72$. I just say $2^3 \times 3^2$ then I take the one for $log2$ and I multiply by 3 and the one for $log3$ I multiply by 2 then I add and get the results (Informant. 39, 2020).

In the process after Jack had explained the above result, another interviewee called Mathew claimed that even if Jack was used to that method the arrangement according to how they were taught was not correct considering how he had demonstrated some steps. Due to this, Mathew justified that the problem was that the teacher did not explain each point step by step. Consequently, that was the reason for conflict because even Jack who had just expounded his method was astonished by the statement. Mathew illustrated that the teacher's method in explaining the problem was that after getting the factorization of 72 as $2^3 \times 3^2$, then you were to write them in logarithm notation before proceeding to write them in index form. Therefore, the logarithm notation as was explained by Mathew was as follows $3\log 2 + 2\log 3$. Mathew continued to explain the process for writing the problem in index notation as:

$$3\log 2 + 2\log 3 = 2^3 \times 3^2$$

After writing the problem in index notation, Mathew concluded that the rest of the procedure to get the answer remains the same by following what Jack did. Mathew continued to claim that the problem was only on the arrangement from logarithm to index notation. He explained as follows:

> Maybe he (referring to Jack) just confused the arrangement but the teacher did not explain the procedure part by part because he could just get straight to the point and say for example here it will be 3log2 + 2log3. So the teacher never explained each step clearly (Informant. 38, 2020).

The sentiments above from the students call upon teachers of mathematics to ensure that students are systematically taken through problem solving so as to develop better conceptual understanding in solving mathematical problems. The study emphasized that teachers should ensure that the explanations provided during problem solving should resonate with students' lived experiences to ensure that the students do not view the concepts as abstract. Based on this, the study emphasized that teachers should make use of contextualization in mathematics teaching so that students are prepared adequately to develop better skills in solving mathematical problems.

From the themes discussed above, the study found that cognitive conflict provides opportunities for students to (co)construct their understanding of mathematical concepts. As such, teachers should endeavor to encourage cooperative learning approaches by providing opportunities for group discussions, and by encouraging students to consult from their peers and the teacher whenever they encounter challenges with problems in mathematics (Makonye & Khanyile, 2015; Sayce, 2010; Webb et al., 2019). In addition, teacher educators should equip student-teachers with skills on how to set mathematical tasks that require higher-order reasoning skills so that students can have deeper conceptual understanding and thereby achieve the intended learning outcomes (Bloom, & Krathwohl, 1956).

As a result of the teacher's behaviorist stance, the study found that some teachers' still employ behaviorism by making the lesson to be teacher-centered consequently they fail to acknowledge that students learn better when their experiences are taken into account. Therefore, this study emphasizes that it will be important for teachers to adopt a constructivist stance to acknowledge and tap into students' ideas during teaching to build on their lesson topic of discussion (Graffam, 2003; Vosniadou & Verschaffel, 2004). Further, teachers should employ cognitive conflict to facilitate students' mastery of content and guide the students to develop skills for better conceptual understanding (Chambers & Timlin, 2019; Hermkes et al., 2018; Kang et al., 2010; Rahim et al., 2015). Moreover, this

study has underscored that teachers who are teaching mathematics in lower secondary schools (Form 1 & 2) should have an idea about the content covered at these levels that will enable them to plan their lessons on what students know to facilitate understanding of the required variation by students about the concept during teaching (Hermkes et al., 2018; Mulungye et al., 2016; Sutopo, 2014). Hasty presentation of mathematical concepts by teachers to students during teaching makes students experience more cognitive conflict. Therefore, this study also advocates that teachers should contextualize the content so that it resonates with students' lived experiences.

4.4 Gender Differences on Learners' Approaches to Cognitive Conflict in Mathematics

Cognitive conflict can make students develop mathematical skills that are required to solve different mathematical problems by conceptual understanding as opposed to memorization. This will help the students develop critical thinking skills so that they can give explanations on how different solutions to different mathematical problems have been obtained. This study investigated students' opinions on student gender with more challenges in mathematics. The students' feedback has indicated that as compared to males, females have more challenges in mathematics. This is because the result shows that the majority (69%) of the students indicated that female students have more challenges with mathematics. Therefore, the findings agree with Samuelsson and Samuelsson (2016) who also found that females had more challenges with mathematics as compared to males.

These challenges are as a result of difficulties the students faced during mathematics teaching and learning. This study also investigated students' opinions as to why they have challenges in mathematics. The study found that males had challenges in mathematics because most of their teachers felt that they understand mathematics fast and so they explained concepts to them very fast which made them experience cognitive conflict as a result of fast concept explanation during mathematics teaching as also explained by the findings from the interview. Therefore, this result supports the findings by Bowe et al. (2017), who found that teachers believed that males possess cognitive abilities to solve mathematics problems as compared to females. From the findings, (50%) of the students

also explained that females develop a negative attitude due to difficulties they do experience in solving problems and hence they consider mathematics as a hard subject that should be left for males. Also, (9%) of the students explained that females have challenges with Mathematics because they are not found in most mathematics related jobs as most of them are employed as secretaries in different offices.

The study further investigated students' attributions for a difficulty to understand a problem in mathematics. The responses obtained from the students are indicated in Figure 4.8 below.

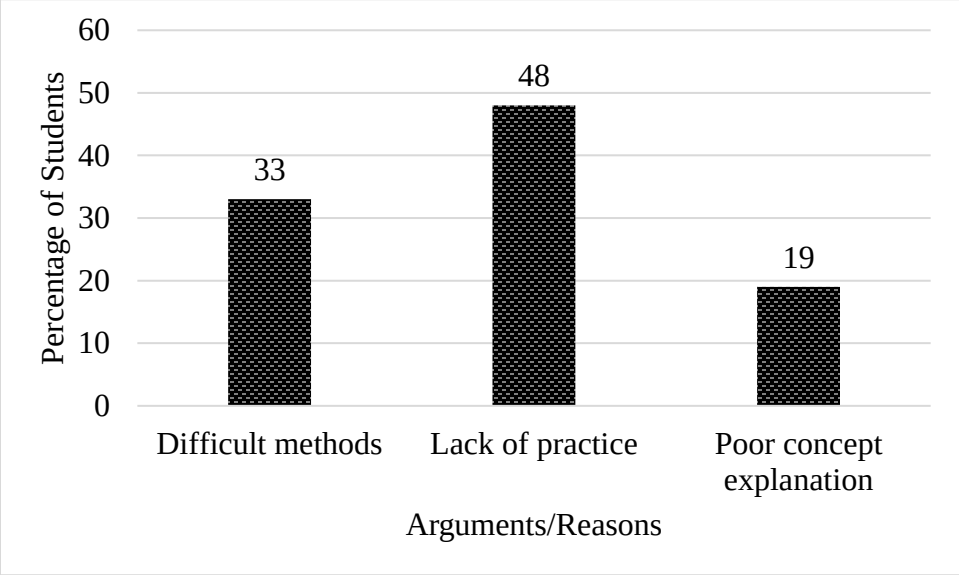

Figure 4.8: Students' Attributions for Difficulty in Understanding a Problem in Mathematics

Figure 4.8 above shows students' attributions for the difficulty in understanding a problem in mathematics. As indicated above, 33% of students explained that they failed to understand problems in mathematics as a result of confusion due to different methods that seemed easier but difficult to understand during mathematics teaching. The majority (48%) of students explained that they experienced difficulties due to failure to understand the questions as a result of a lack of practice as well as a negative attitude. Additionally, 19% explained that the difficulties are due to poor concept explanation by their mathematics teacher as a result of poor communication during mathematics teaching and learning.

Consequently, these factors made students have low grades in mathematics. Therefore, after getting that the students had an idea about student gender with more challenges in mathematics as well as what each student felt about the challenges in mathematics, the study sought the students' ideas on how they solved those challenges so that they continue with mathematics learning. To achieve this, the study gives the descriptions of information about students and cognitive conflict in mathematics as well as the justification on whether there are significant gender differences about how the students approach cognitive conflict in mathematics. Table 4.2 below outlines students' opinions on cognitive conflict and mathematics learning.

Table 4.2: Descriptive Statistics for Students' Opinions on Cognitive Conflict and Mathematics Learning

The study variables	Mean	Mode	Median	SD	N
Have experienced confused moments due to (student/teacher) method used in solving mathematics problem	1.13	1	1	0.34	350
Male students are more likely to solve challenging mathematics problems through group work than female students	2.23	1	2	1.34	350
Female students are more likely to score highly in mathematics than male students	3	4	3	1.33	350
Male students are more likely to score highly in mathematics than female students	2.43	1	2	1.36	350

From Table 4.2, the results show the mean, mode, and median of students' opinions on cognitive conflict and mathematics learning. Generally, the result indicates that majority (87%) students agreed to most of the items that were testing students and cognitive conflict in mathematics except one variable where the majority (69%) of students disagreed. Therefore, the findings of this study confirm the findings by Hacieminoglu (2016), and

Samuelsson and Samuelsson (2016) who argued that males are more likely to solve challenging problems in mathematics, they also have more interest in mathematics that makes them have better grades in mathematics as compared to females. The study also found the percentage of students who use confusing moments to improve their skills as well as their attributions on inadequacy in topics coverage as a factor that promotes cognitive conflict in mathematics learning. Based on the utility of cognitive conflict by students, the study investigated students on the relevance of the content covered in relation to improvement in their reasoning skills. The results are shown in Figure 4.9 below.

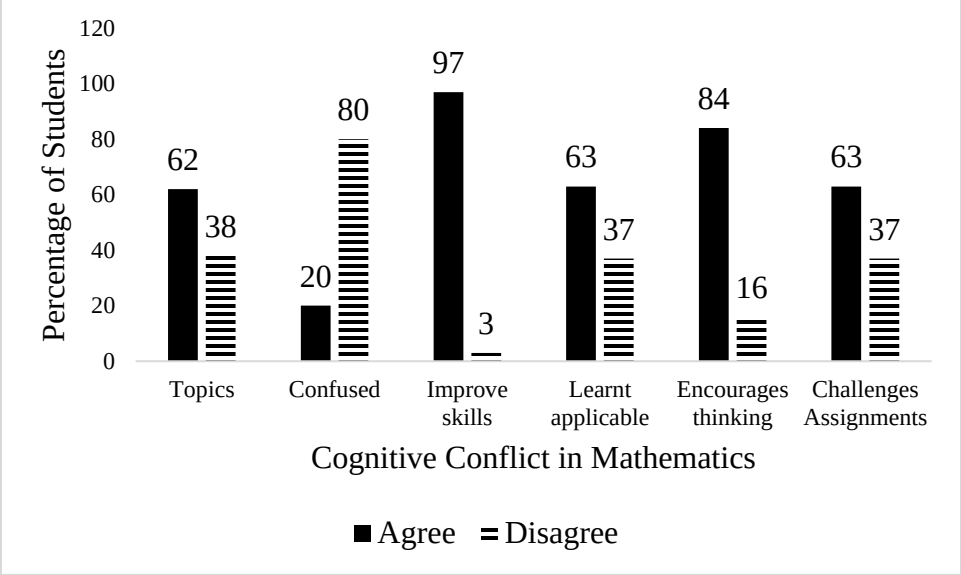

Figure 4.9: Students' Response to Cognitive Conflict in Mathematics

Figure 4.9 above, shows students' responses on cognitive conflict in mathematics. As shown above, on students' attribution for cognitive conflict as a result of inadequate topic coverage, 62% of students agreed that confusion is brought about by inadequacy in topics covered where they failed to understand concepts as a result of poor teaching. Research shows that when students fail to understand the concept taught in a topic, they are likely to experience difficulties and make errors in solving problems that require the application of concepts under that topic (Maharani & Subanji, 2018).

Cognitive conflict moments can motivate students to have an interest in what the lesson is about and view the situation as friendly to everyone. Further, the result indicates that the

majority of students (97%) always try to improve their mathematical skills as a result of cognitive conflict. Therefore, teachers need to plan their lessons based on cognitive teaching strategies that promote students' conceptual understanding so that by the end of the lesson the students can develop better skills in problem solving. The result also indicates that 63% of students agreed that they always had challenges when working on their mathematics assignment. Hence, teachers need to be focused on students during mathematics learning by observing how they are solving different mathematics problems and adopt an appropriate scaffolding strategy to help the students to develop better problem solving skills for conceptual understanding. This will help the students to gain skills in solving different mathematical problems without experiencing difficulties. To establish whether there were significant gender differences in learners' approaches to cognitive conflict in mathematics, an independent samples t-test was carried out, and the result indicates that male students obtained a statistically significant higher mean score than female students in most of the variables that were being tested. This study's results indicate that male students experience cognitive conflict more in mathematics as compared to female students since they possess cognitive abilities to solve mathematics problems as compared to females (Bowe et al., 2017). The results are as shown in Table 4.3 in the next page.

Table 4.3: Independent Samples t-test for Gender Difference

	Male(n=186)			Female(n=164)			
Variables	Mean	SD	Std. Error difference	Mean	SD	T	Sig;(2-tailed)
Have experienced confused moments due to(student/teacher) method used in solving mathematics problems	1.19	0.39	0.04	1.06	0.2	3.603	0
Male students are more likely to solve challenging mathematics problems through group work than female students	1.97	1.26	0.15	2.53	1.5	-3.820	0
Female students are more likely to score highly in mathematics than male students	3.3	1.31	0.14	2.93	1.3	2.569	0.011

The result from Table 4.3 above, shows Levene's test that was used to assess the null hypothesis by comparing variances and means between the two groups (male and female students) if equal to each other. Also, the result of the test was to give guidance on whether the null hypothesis is being retained or rejected. The Levene's test rejects the null hypothesis if the resulting statistic is not significant. The finding indicates that the items tested for gender differences present a significant statistical difference. As can be seen, three sole variables that recorded significant gender difference are, had experienced confused moment due to the student or teacher method in solving mathematics problem, males are more likely to solve challenging mathematics problems through group work than

female students, and female students are more likely to score highly in mathematics than males.

The study obtained a significant gender difference ($t=3.603$, $p<0.025$) on the variable that was testing whether students had experienced confused moment due to the student or teacher method in solving mathematics problem. This indicates that males experienced cognitive conflict more in mathematics as compared to females. Therefore, even if male students experienced cognitive conflict more as a result of different mathematical formulas that are being used by different students and mathematics teachers to solve problems, female students also experience the situation but not at the same rate as males. This quantitative result is supported by qualitative information obtained from students both from interviews discussed above as well as in questionnaires about how the experiences gained from these moments changed their approaches to mathematics.

The study found that (39%) of the students explains that as a result of cognitive conflict, males tend to develop a positive attitude in new concepts, do more consultation from their mathematics teachers and peers so that they can overcome the difficulties. In addition, (51%) of the students also explained that due to cognitive conflict, males learn more from revision materials as compared to females. As compared to males, females also experience cognitive conflict in mathematics as they try to apply both methods from teachers, peers, and get confused due to difficulty to understand and apply the methods. Therefore, due to cognitive conflict, the study found that (71%) of the students explained that females tend to develop a negative attitude and hate mathematics and view it as a difficult subject with concepts that look confusing. This also supports the findings by other scholars who found that males possess cognitive abilities to solve mathematics problems as compared to females who were also explained to have more challenges with mathematics (Bowe et al., 2017; Samuelsson & Samuelsson, 2016). Therefore, this study has confirmed that cognitive conflict is experienced mostly by students who have an interest in mathematics and do a lot of practice to obtain good grades (Pekrun et al., 2017; Putwain et al., 2018).

Secondly as indicated from the Table 4.3 above, on whether male students are more likely to solve challenging mathematics problems through group work than female students, the study has obtained a significant gender difference ($t=3.82$, $p<0.025$). This indicates that

even if female students also solve challenging mathematics problems through group work, they do not perform it at the standard to which male students are using the same method to solve different mathematical problems. These study results support the findings by Pekrun et al. (2017), Putwain et al. (2018) who argued that students who enjoy mathematics always make use of deeper learning strategies that result in better grades by them in mathematics and vice versa. Moreover, on the question as to whether 'female students are more likely to score highly in mathematics than male students', the study result indicates a significant gender difference ($t=2.569$, $p<0.025$). This means that majority (69%) of the students do not support the statement. Therefore, from the above results, we reject the null hypothesis and conclude that there are significant gender differences in learners' approaches to cognitive conflict in mathematics.

4.4.1 Cognitive Conflict in Mathematics Teaching and Learning

In addition to comparing gender differences in learners' approach to cognitive conflict in mathematics teaching and learning, the study sought to find out information about content understanding and applicability of the concept taught by teachers to students. To obtain this the study tabulated mean for males and female students, mode, median, and standard deviation of the variables under this category. The results are shown in Table 4.4.

Table 4.4: Gender and Cognitive Conflict in Mathematics

Variables	Males' Mean	Females' Mean	Mode	Median	SD
There are topics I was not taught well in mathematics	2.67	2.59	2	2	1.372
I get confused during mathematics lessons	3.82	3.62	4	4	1.252
I do try to improve my mathematics skills	1.38	1.43	1	1	0.638
I am always able to apply what I learned in mathematics	2.27	2.45	2	2	1.214

What I learn in mathematics encourages me to think	1.82	1.85	1	2	1.068
I do experience challenges with mathematics assignments	2.37	2.38	2	2	1.287

From Table 4.4, more males agreed that there are topics they were not taught well as compared to females. This supports the earlier statement that due to cognitive conflict males tend to develop more interest in finding solutions to challenging problems than females in mathematics learning, which might be the reason behind them obtaining a higher mean as compared to females. Consequently, due to more practice, males could identify some concepts in the previously covered topics that makes them confirm that some of those topics were not well taught. The result indicates that both student gender develops an interest to learn because they all agree that as a result of mathematics difficulties they always try to improve their mathematics skills. Most females explained that what they learn in mathematics is always applicable as compared to males. Therefore most of them seem to depend on what is taught during the lesson as compared to males who go further to research more about the lesson topic and find some difficulties in applying the concept taught during the lesson. More females indicated that what they learn in mathematics encourages them to think as compared to males. Therefore this indicates that as compared to males, females also make use of cognitive conflict to identify more ways on how they can solve challenges when working on their mathematics assignments.

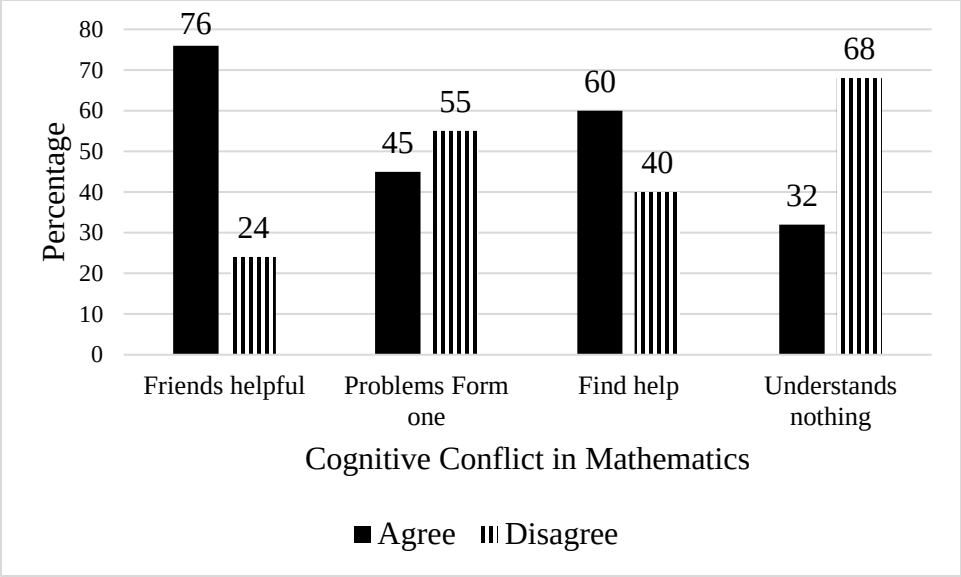

Figure 4.10: Identification of Cognitive Conflict by Students and their Reactions to the Situation

Figure 4.10 above, shows that as a result of cognitive conflict, students try to find ways to react to conflict so that they can learn. The result indicates that 45% of students agreed that they experience cognitive conflict because their teacher never explained points clearly in Form One. Based on this, most students try to solve their mathematical difficulties by either seeking help from their peers or by revising different reference materials in mathematics. This is because a point that was not well explained can be identified by those who do more practice so that they can develop ways of solving the problem. Apart from peers being helpful, the study tried to find out the percentage of students who sought help in areas they experienced difficulties. This indicates that students experience cognitive conflict in mathematics and develop interest depending on those moments so that they can find ways of solving the mathematical difficulties. Among the students who seek help, 60% agreed that they find help concerning the areas they had challenges.

This implies that a good number of students failed to get assistance in areas they had difficulties in mathematics. As a result, this might lead to poor scores by the students in the future if the situations were not identified and corrected. Finally, on whether the students concentrate in class and understand nothing, this study found out that 32% of the students agreed that they concentrate in class and understood nothing. Therefore, this

finding supports Hermkes et al. (2018) who argued that teachers need to facilitate students learning by employing scaffolding strategies that will offer guidance to the students to concentrate during mathematics learning to ensure conceptual understanding for better problem solving.

4.4.2 Teachers' Arguments on Students Gender Approaches to Cognitive Conflict in Mathematics

The study obtained several responses from different Form Two teachers based on students' gender concerning the cognitive conflict in mathematics. Table 4.5 below, represents the mean, mode, standard deviation, and median of different study variables on teachers' opinions about students and mathematics learning.

Table 4.5: Teachers' Response on Questions Related to Students and Mathematics Learning

Variables	Mean	Mode	SD	Median
A student with more challenges in mathematics	2.06	2	0.48	2
There are topics in mathematics where students get confused with my strategy	1.44	1	0.5	1
I had witnessed student(s) confused due to my strategy in solving problems	1.17	1	0.38	1

From Table 4.5 above, on whether there are topics in mathematics where students get confused due to the teacher's strategy of problem solving, the results indicated that teachers agreed to the statement. This was further confirmed during the study by determining whether teachers have witnessed occasions where students were confused due to their strategy in solving problems. The result indicated that teachers had witnessed the situations during their mathematics teaching as well as different occasions when interacting with students who had mathematics problems.

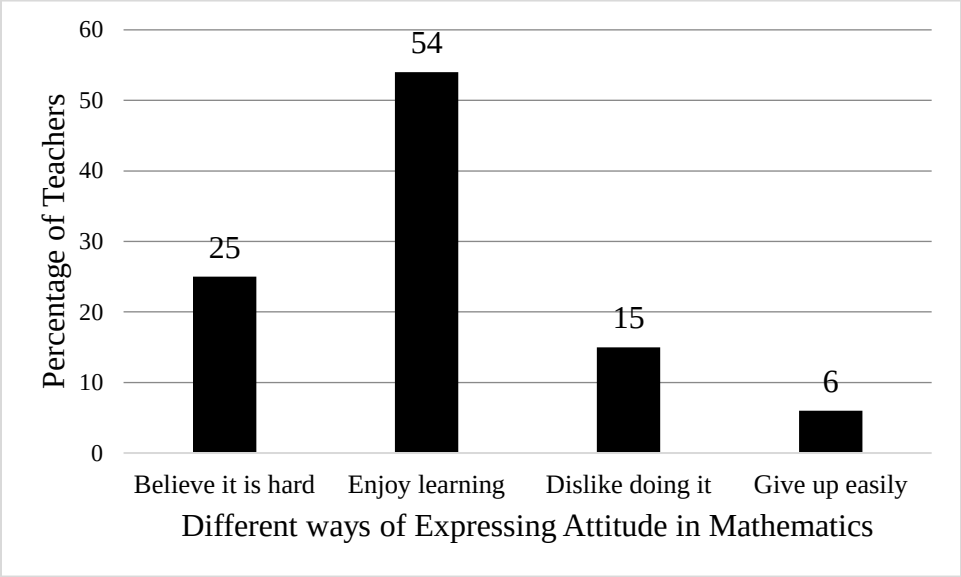

Figure 4.11: Opinions of Teachers' on Different Attitudes by Students in Mathematics

The study found out from teachers why different students possess different attitudes in mathematics during teaching and learning situations. A good number of teachers responded by giving reasons as per their perception as to why students possess different attitudes in mathematics. In this, 54% explained that students have a positive attitude in mathematics because they enjoy learning and consult in areas they experienced difficulties as well as participating well during the lessons. They added that these students were also willing to take science-oriented careers. Furthermore, 25% of teachers gave their opinions by explaining that their students had a negative attitude in mathematics because they believed that mathematics is a hard subject.

The teachers also explained that these students always failed to do assignments as well as consulting in areas they had challenges that resulted in their poor performance. Therefore, the results from this study support the findings by other researchers who argued that there is a relationship between student's attitude and achievement in mathematics (Hacieminoglu 2016). This is because students who have a positive attitude in mathematics develop more interest in the subject and as a result, they choose a profession in science-oriented careers

related to mathematics (Cecil & Williams, 2011; Kanny et al., 2014; Legewie & DiPrete, 2014; Sadler et al., 2012; Wang & Degol, 2017).

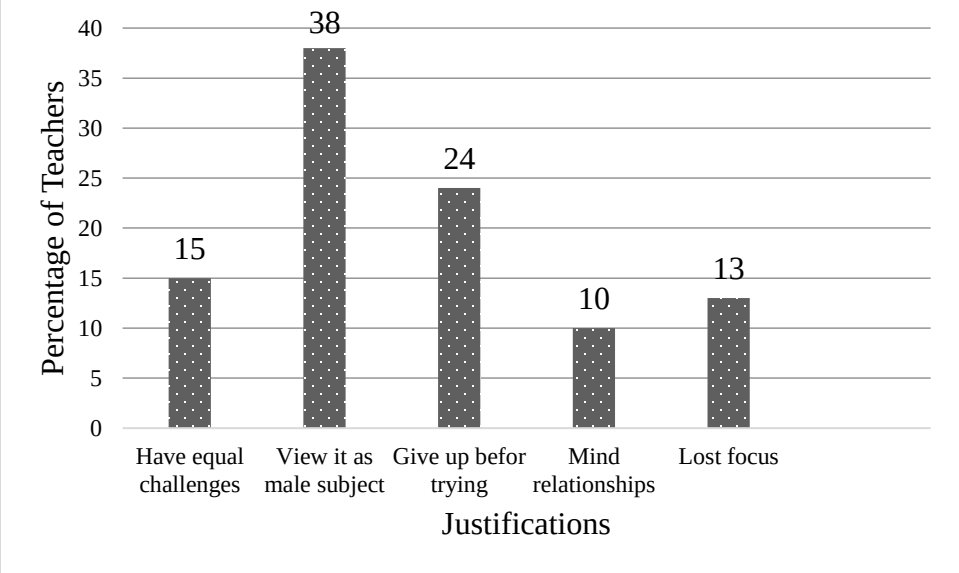

Figure 4.12: Teachers' Arguments as to why Students have Problems with Mathematics

On the question about justifications by teachers concerning why students have challenges in mathematics 38% of teachers clarified that females have more challenges because they view mathematics as a subject that is supposed to be handled by males. Also, 24% of teachers explained that their students had challenges in mathematics because they gave up very fast even before they try to solve the mathematics problem given. 15% of teachers explained that both student genders had equal challenges with problem solving in mathematics because they always competed favorably and had equal performance in mathematics. The study also found that 13% of teachers argued that challenges with their students in mathematics are because some of the students had lost focus in schooling and had decided to concentrate on negative peer pressure. To confirm this argument 10% of the teachers stated that their students had challenges with mathematics because they spent more time on relationships and never concentrate in class.

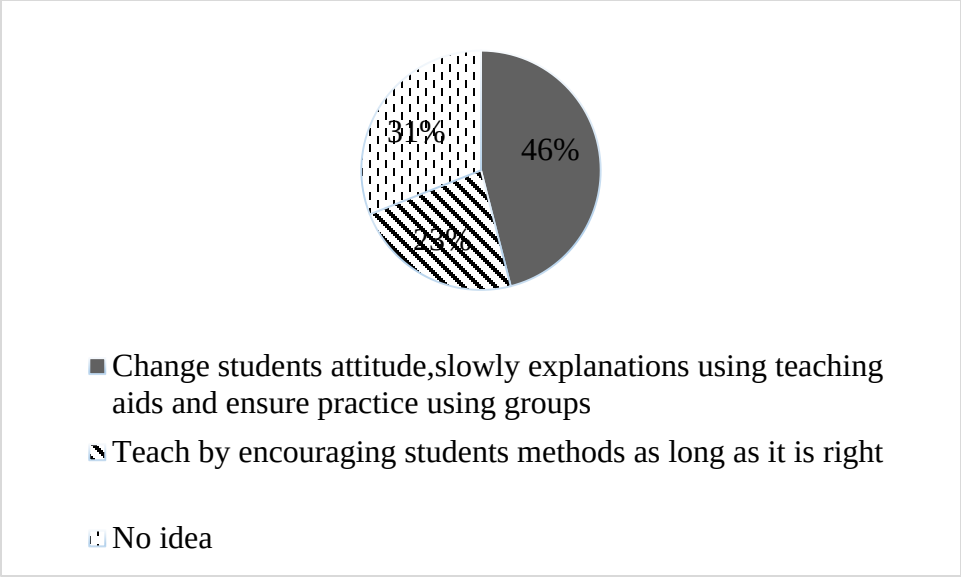

Figure 4.13: Teachers' Ideas on how to Use Cognitive Conflict to Improve Mathematics Learning on Different Student

On the question about how cognitive conflict can be used to improve mathematics learning on different students, from Figure 4.13 above, 46% of teachers explained that during cognitive conflict situations, teachers should first change the students' attitudes from negative to a positive attitude so that they develop an interest in learning. They also emphasized that after changing the attitude of students so that they develop an interest in learning, teachers should as well ensure slow concept explanation accompanied by the use of available teaching resources. At the end of the teaching, they also suggested that teachers should give students work so that they can practice by making use of group discussions. Also, 23% of them explained that teachers should teach new methods and encourage students to use their methods if and only if the method is right. The results discussed above on how teachers should utilize cognitive conflict to support students' understanding of concepts, support the findings by Chambers and Timlin (2019) who argued that teachers need to plan on how they are going to engage students during teaching by identifying teaching resources that they are going to use in explaining concepts for better conceptual understanding by students.

From this research question, therefore, this study has underscored the need for teachers to motivate students to have an interest in the lesson. This will make students especially

females to develop a positive attitude in mathematics as males by having an interest in the lesson topic of discussion as well as on the subject as a whole towards attaining good grades by employing cognitive conflict for better conceptual understanding. Also, the study found that cognitive conflict promotes students' learning on both gender, therefore, teachers should make use of this teaching-learning strategy to enhance student understanding of concepts. This, therefore, calls for all teachers to help students gain factual knowledge on how different problems are solved as well as conceptual knowledge so that the students can be able to identify the interrelationships among different mathematical algorithms that enable the algorithms to work together. Moreover, the students should be assisted to possess procedural knowledge so that they can be able to make use of different algorithms taught properly that will improve mathematics learning.

The results too indicate that teachers find difficulties in teaching some mathematical topics therefore, the study call for school administrators and mathematics educators to always work together in arranging in-service training for teachers of mathematics to gain skills in order to teach each and every topic without experiencing difficulties. Also, the training will make the teachers possess skills on how cognitive conflict can be useful in promoting mathematics learning on different students to possess the factual, conceptual, and procedural skills discussed towards better problem solving. The application of cognitive conflict as a teaching strategy will also help teachers to recognize the value of Bloom's taxonomy for cognitive skills to develop lesson objectives that are Specific, Measurable, Achievable, Realistic, and, Time-bound (SMART) prior to actual teaching. This will improve students' mathematics learning because the cognitive skills are considered by teachers in evaluating students against the lesson objectives that dwell on, knowledge, comprehension, application, analysis, synthesis, and evaluation of the content taught. This, therefore, will make teachers teach the concepts in different topics in a way that students can be able to, remember, and understand the concepts taught, apply as well as analyze the content covered, evaluate, and even create more of what has been discussed during the lesson for better academic achievement (Wilson, 2016).

The study aimed at exploring cognitive conflict on mathematics teaching and learning in public secondary schools. Based on the information obtained, the study underlines that

cognitive conflict is useful in students' mathematics learning for better conceptual understanding because the majority (97%) of students indicated that they always improve their mathematics skills as a result of cognitive conflict. Therefore, the study underscores the need for teachers to make use of cognitive conflict to facilitate students' mastery of content by accommodating students' ways in problem solving and guide the students in developing skills to solve different problems critically (Hermkes et al., 2018; Rahim et al., 2015). This will promote students to develop an interest in mathematics by adopting deeper learning strategies such as cognitive conflict to obtain quality grades in mathematics (Chow & Treagust, 2013; Pekrun, 2006; Pekrun et al., 2017).

On whether there are significant gender differences in learners' approaches to cognitive conflict in mathematics, the results indicate that as compared to females, males experience more cognitive conflict in mathematics. The study also found that due to cognitive conflict in mathematics, female students tend to develop a negative attitude, hate, and view mathematics as a male subject with difficult formulas to understand. Based on this, therefore, the findings of this study support the arguments by other researchers that difficulties in understanding mathematics concepts make more females lose interest in mathematics as well as mathematics related careers due to poor grades they do obtain in the subject as compared to males (Cecil & Williams, 2011; Kanny et al., 2014; Legewie & DiPrete, 2014; Sadler et al., 2012; Wang & Degol, 2017).

To ensure better conceptual understanding by students, teachers should plan to utilize cognitive conflict in occasions where students seemed confused to understand the problem being discussed (Chambers & Timlin, 2019). The study indicates that during cognitive conflict moments, teachers should ensure that students developed a positive attitude by encouraging them to have an interest in mathematics and explain concepts to them slowly so that they can learn. Also, the study supports the findings by Sayce (2010) who also argued that during the cognitive conflict, teachers need to make use of teaching resources accompanied by several demonstrations, ensure group discussions and give students assignments so that they can practice what has been discussed. Moreover, teachers need to develop an interest in students' methods and relate the methods to the new concept so that the lesson is learner-centered with concepts being explained from simple to complex.

Interestingly, teachers also argued that cognitive conflict is the most tool to be used to enhance mathematics learning by ensuring that teachers make use of team teaching as well as giving practical examples to students, and apply the teaching to a real-life situation.

4.5 Teachers' Preparedness to Scaffold Mathematics Learning using Cognitive Conflict

This study also investigated the teachers' preparedness to scaffold mathematics learning using cognitive conflict. The study investigated how different teachers responded to moments when students seem confused with their method of solving a problem that appeared to differ from the teachers' method. The result from the teachers' response is shown in Figure 4.14 below.

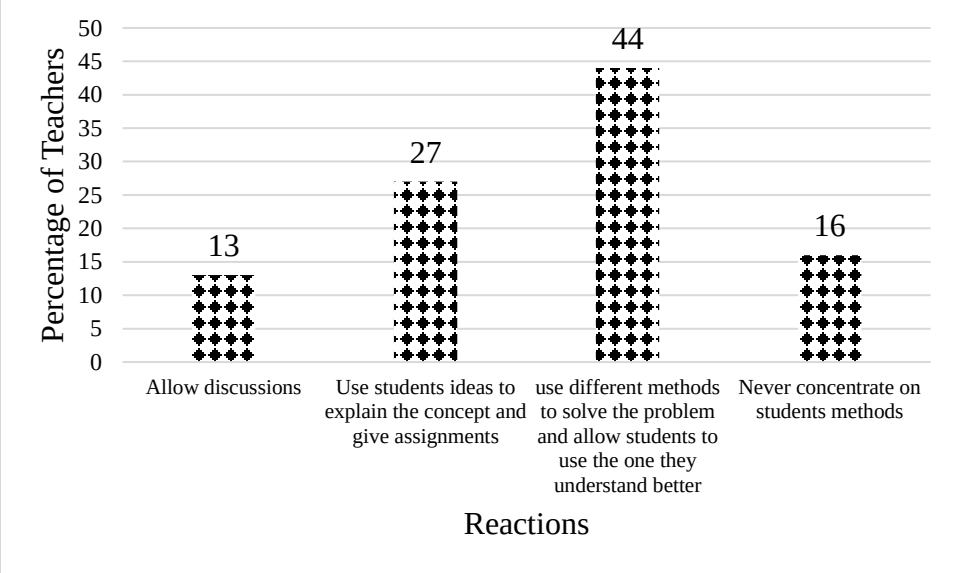

Figure 4.14: Teachers' Response on how to Handle Confusion Moments

From the Figure 4.14, 13% of teachers responded by explaining that during confusion moments when students have their ways of solving mathematics problem that appeared to be different from that of the teacher, they always group the students, then take time in explaining the concepts to them in finding more solution to the problem as compared to primary and Form One skill. Also, 27% of the teachers explained that under that condition they give the students time to explain the problem and then show them the new method. They explained that, in employing the new method to guide the students, they always try

to modify the method to an extent that it presents a different concept to the problem which students had never witnessed. Moreover, they explained that after the presentation of both methods, they then relate their methods to students' method to ensure that the students understand the concept. They concluded that after they have agreed they then give students assignments on different problems of the same kind to improve students' conceptual skills.

The results also indicate that 44% of the teachers solved the problem by first using the student method. Secondly after using the students' method they then solve the same problem using their method and allow students to use the method which they understand based on what they have gained from the discussions. Based on the above discussions, this study concurs with Iiskala et al. (2011), Maharani and Subanji (2018), and Sayce (2010) who argued that during cognitive conflict moments teachers are supposed to engage students in discussions so that as students discuss they can gain more skills for problem solving. This implies that for teachers to utilize cognitive conflict in mathematics learning effectively they should give their attention to students during problem solving situations, therefore this study underscores the need for teachers to ensure that during scaffolding collaborative mathematics teaching they give more attention to students and teach them how to solve problems critically.

Table 4.6: Teacher' Preparedness in Mathematics Teaching and Learning

Variables	Mean	Mode	Median	SD
Attend mathematics lessons in time	1.38	1	1	0.854
Apply mathematics teaching to real-life	1.75	2	2	0.812
Revise topics with students	1.88	1	2	0.981
Use several demonstrations in explaining concepts	1.85	2	2	0.772
Allow students' participation during lessons	1.35	1	1	0.526

The study sought to examine whether teachers are always prepared to scaffold learning by employing different scaffolding strategies to teach mathematics. From Table 4.6, it shows the mean, mode, median, and standard deviation of the variables which were testing teacher preparedness to scaffold mathematics learning using cognitive conflict. From the result

above, teachers agreed to all the items which were testing teacher preparedness to scaffold mathematics learning using cognitive conflict. Scaffolding is necessary for guiding students in mathematics so that they can be able to understand concepts better. Further, to ensure that the study obtains teachers' ideas on how they employ various scaffolding strategies to improve students' mathematics learning based on cognitive conflict, teachers were requested to indicate their views and the result is as shown in Figure 4.15 below.

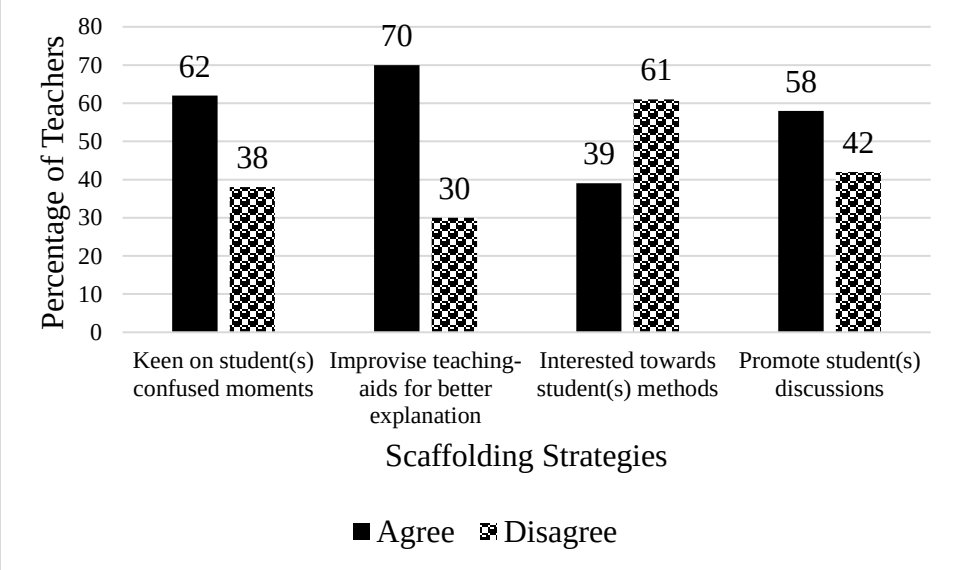

Figure 4.15: Teachers' Views on Scaffolding Strategies towards Mathematics Learning Based on Cognitive Conflict

On the item which was testing teachers' keenness to identify confusing moments on students and identify a method to help the students overcome the situation and learn, the result as shown from the Figure 4.15, indicates that majority of teachers (62%) agreed that they always had a strategy of helping students to overcome confusion with mathematical concepts. On whether teachers look forward to students' strategies of problem solving in mathematics, the study found that 39% of teachers agreed that they are interested in students' strategies in problem solving in mathematics.

This implies that the majority of teachers are not interested on students' strategies in problem solving in mathematics. This quantitative result is supported by qualitative information obtained about this study during interviews where students argued that their

teachers do not recognize their methods in problem solving and considered such methods as time-consuming. The result also confirms the findings by Mulungye et al. (2016) who found that majority of teachers do not support students' methods in problem solving in mathematics. Therefore, scaffolding mathematics learning using cognitive conflict will help these teachers to have an interest in students' methods so that they plan their lessons based on activities aimed at offering guidance to students' preferred methods for better conceptual understanding (Sutopo, 2014).

The study further investigated whether teachers always encourage students to think of their strategies for problem solving after and before the lesson. The study discovered that 58% of teachers agreed that they encourage students to think of their strategies in mathematics. This study found that the majority of teachers (58%) always encourage students to think of their strategies after teaching but they are not interested much in such students' strategies as discussed previously. Based on this, the study supports the argument by Hermkes et al. (2018) that in scaffolding teachers need to relate the content to the most important factor which affects student's conceptual acquisition during learning that is student preferences in problem solving. This will help the teacher in identifying appropriate scaffolding strategies to offer guidance to students on how their methods can be modified based on the mathematical problem to be solved.

The result too indicates that there are several topics in which different students have difficulty in understanding whereby most teachers explained that they face difficulties with students in topics such as *Indices and Logarithms* as well as *Surveys and Bearing*. Other suggested topics also include *Commercial Arithmetic*, *Transformation, Area and Volume of Solids, Trigonometry, Longitude and Latitude, Sequence and Series* as well as *Probability*. To overcome confusion on these topics, most teachers recommended that during teaching, teachers should try to relate the students' prior knowledge to the content to be taught. Additionally, they encouraged teachers to make use of team teaching, teaching aids, as well as giving assignments and practical examples to students during the lessons. Others also emphasized on the use of discussions, slow concept explanation, and applying the teaching to a real-life situation as well as giving group work to students.

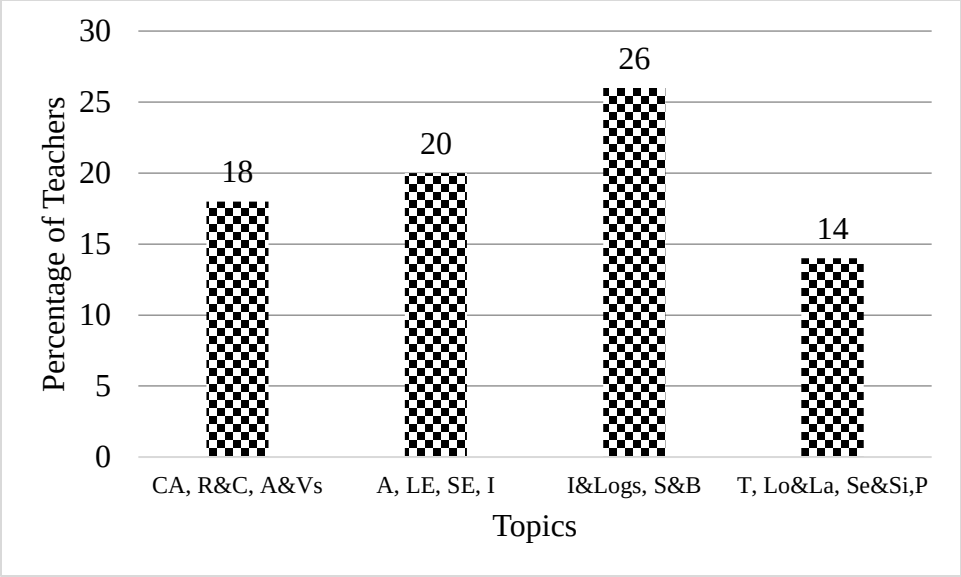

Figure 4.16: Topics where Students are more Likely to Get Confused with Teachers' Strategy of Solving Problems

As shown in Figure 4.16 above, 18% of teachers explained that students are more likely to get confused with their methods of solving problems in topics like *Commercial Arithmetic (CA), Reflection, and Congruence (R & C), Area and Volumes of Solids (A & Vs)*. Also, 20% of teachers explained that they experienced the situation in *Algebra (A), Linear Equations (LE), Simultaneous Equations (SE),* and *Integers (I)*. Moreover, 26% of teachers explained that the situation was more in *Indices and Logarithms (I & Logs), Survey, and Bearing (S & B)*. Finally, 14% of teachers explained that they had witnessed the situation in *Trigonometry (T), Longitude, and Latitude (Lo & La), Series and Sequence (Se & Si), and Probability (P)*.

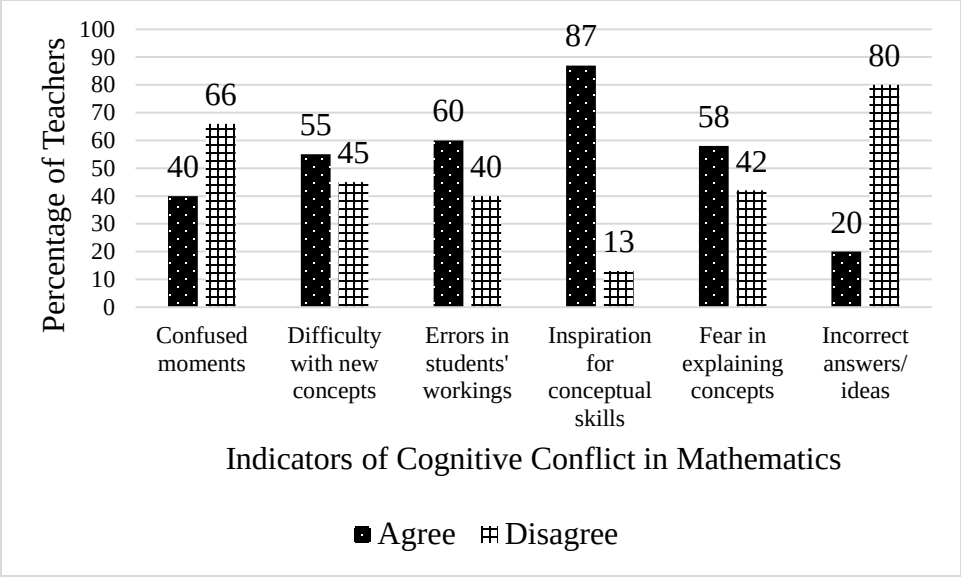

Figure 4.17: Teachers' Comments on Indicators of Cognitive Conflict in Mathematics

This study was also interested in getting teachers' comments about different situations that occurred during mathematics learning as a result of cognitive conflict. Therefore, from Figure 4.17 above, 40% of teachers agreed that their students were often confused during mathematics lessons. Also, 55% of teachers agreed that their students always had difficulties with new concepts in mathematics, while 60% of teachers agreed that their students made errors in solving different mathematical problems.

On motivation to students during moments where they seemed not to understand concepts, 87% of teachers agreed that they do inspire their students to develop a positive attitude towards a conceptual understanding of mathematical concepts. On whether teachers have difficulties in teaching some topics and feel uncomfortable in teaching them, the study found that 58% of teachers agreed that they do have difficulties in teaching some topics in mathematics. Finally, on whether learners' misconceptions make teachers lose the focus of the lesson and present wrong ideas in mathematics, the study indicates that 20% of teachers agreed with the statement. The study also sought students' views about their teachers' preparedness to scaffold mathematics learning using cognitive conflict during mathematics teaching. The findings are as shown in Figure 4.18 in the next page.

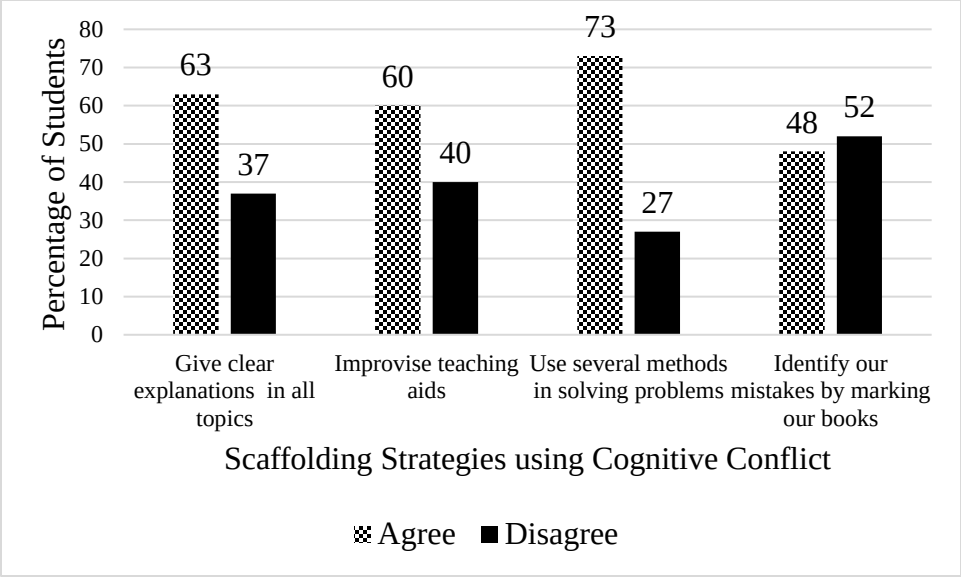

Figure 4.18: Students' Views on Teachers Preparedness to Scaffold Mathematics Learning using Cognitive Conflict

The study investigated teachers' ability to teach all topics well by providing students with adequate explanations. As indicated in Figure 4.18 above, 37% of the students disagreed that their mathematics teachers do not teach all the topics well. These findings are agreeing with the result obtained from teachers about whether there are topics they have difficulty to teach, where a good number of them indicated that there are topics they are not comfortable to teach. Also tested on both students and teachers was about the provision of relevant teaching materials by teachers in mathematics. The study found that 60% of students agreed that their teachers improvise teaching materials in mathematics. Students need to learn several ways of solving problems hence teachers should make use of several demonstrations during teaching by using teaching resources to enable students to understand concepts better.

On whether teachers mark and return students' work so that they can prepare to correct students' mistakes after identifying students' problems from mistakes they made in problem solving, this study found that 52% of the students disagreed. Therefore, this supports the reason why most students indicated that they had challenges with their assignments because most teachers do not identify and correct students' mistakes in finishing their tests. This study supports the findings by Chick and Baker (2005) and Makonye and Khanyile

(2015) who argued that teachers need to identify learners' mathematical errors and correct them because this will increase the students' achievement in learning mathematics. This can be achieved if teachers can identify each student's mistakes by marking the task given after the lesson or after completion of a given topic.

This study points out that teachers' preparedness to scaffold students' mathematics learning using cognitive conflict is an effective strategy for both student gender to gain more knowledge towards quality academic achievement. Therefore, the study has underscored the need for teachers to ensure equal treatment to students during mathematics learning as well as focusing more on female students during cognitive conflict moments so that female student can be assisted to develop a positive interest in mathematics towards attaining good grades because the use of scaffolding is viewed differently by students. Based on this the study calls upon all teachers to always plan to give students challenging tasks not only after the lesson but also upon completion of the topic so that students can develop critical thinking skills in problem solving that will lead to improvement in mathematics learning.

Teacher preparedness is important for planning cognitive activities to engage students in during mathematics teaching for better conceptual understanding if teachers can develop more interest in student preferences (Chambers & Timlin, 2019; Hermkes et al., 2018; Kang et al., 2010). Therefore, mathematics educators and instructional leaders should encourage teachers to develop an interest in students' strategies in problem solving in mathematics. Based on this, the study found that the majority (61%) of teachers are not interested in students' strategies which is an important factor to consider when planning to scaffold mathematics learning based on cognitive conflict. Furthermore, the study supports the arguments by other researchers who argued that teachers need to have interest in students' methods and employ them to plan their lessons based on activities aimed at guiding students to develop a better understanding of the concepts (Hermkes et al., 2018; Mulungye et al., 2016; & Sutopo, 2014). Also, planning lessons based on students' preferences will guide the teacher to identify appropriate scaffolding strategies in modifying the students' methods based on the problem to be solved (Hermkes et al., 2018; Sayce, 2010).

The administrators should also ensure that there is teamwork among teachers so that teachers can consult in areas or topics they have difficulties to teach before the lesson from their colleagues. They should as well ensure that teachers use several demonstrations during teaching by availing teaching materials such as teaching aids that promote a deeper understanding of concepts by students (Clark et al., 2018). The administrators should also encourage teachers to give students work on areas they experienced difficulties to understand during the lesson or upon completion of a topic and mark the exercise so that they can identify and correct students' mistakes in those areas for students' better academic achievement (Chick & Baker, 2005; Makonye & Khanyile, 2015).

Mathematics educators should plan in-service training for teachers on cognitive conflict so that the teachers can possess skills on how cognitive conflict can be used to support students' mathematics learning. Moreover, poor explanations of concepts by teachers in some topics can make students experience more cognitive conflict because the students will have limited knowledge about the concepts in that sub-topic or the whole topic. Based on this, the study has found that the majority (58%) of teachers agreed that they do have difficulties in explaining concepts in some topics discussed previously to students. Therefore, this study underscores the need for administrators and mathematics educators to plan in-service training for teachers based on cognitive conflict towards improving students' mathematics learning by helping students to discover several ways of solving problems that will lead to better concept acquisition and obtaining good grades in mathematics.

CHAPTER FIVE

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the research findings and conclusions based on the analysis of the data collected for this study. The chapter also presents the recommendations and suggested areas for further studies.

5.2 Summary of Research Findings

The study has confirmed that cognitive conflict is useful in mathematics teaching and students' mathematics learning (Susilawati et al., 2017). This is because cognitive conflict helps to improve students' ability to solve mathematical problems, develop critical thinking as well as improving their communication skills (Putra et al., 2019; Widada et al., 2018). The study too supports that cognitive conflict moments should be utilized by mathematics teachers to scaffold students' mathematics learning by explaining concepts that appear difficult to students in a way that the student can understand for better problem solving (Gal, 2019). This, therefore, calls for teachers to possess knowledge such as PCK, CCK, SCK, KCS, KCT, and KCC so that they can use these skills to promote student learning. The study also supports that teachers need to know about CAME and CASE which are programs that underline some guidelines on how teachers can scaffold mathematics learning based on cognitive conflict (Swan et al., 2006).

The study has confirmed that students who experience cognitive conflict are sometimes confused during the lesson, therefore teachers need to identify and assist the students to understand the concepts that contradict their prior knowledge (Sayce, 2010). This study has established that as compared to females, males experienced more cognitive conflict in mathematics and develop more interest in the subject as well as science-related careers. Moreover, the study found that as a result of cognitive conflict, females develop a negative attitude and view mathematics as a male-oriented subject. The study has also confirmed that cognitive conflict can result in students' mathematics anxiety leading to low self-

esteem that can make students' score poor grades in mathematics if the situation is not identified and corrected (Devine et al., 2018).

The study has discussed ways on how teachers can employ cognitive conflict to improve students' mathematics learning for instance relating students' methods to content to be discussed. The study also supports that mathematics educators should plan in-service training for teachers so that they can possess knowledge about cognitive conflict and other teaching strategies such as PBI to ensure fair treatment to students for better problem solving in mathematics (Ashman & Conway, 2017).

5.3 Conclusion

The study has explored information about cognitive conflict and students' mathematics learning from the perspective of research participants. Based on the research findings, the study underscores the need for teachers to encourage students' methods in problem solving as well as develop more interest in students' methods. As noted by other scholars, cognitive conflict has great potential in promoting conceptual change in mathematics and, as such, teachers and teacher educators should endeavor to orchestrate opportunities of cognitive conflict in mathematics to encourage critical thinking among students (Adnyani, 2020; Watson, 2002, 2007).

5.4 Recommendations

Based on the research findings, the study recommends the following: Administrators should encourage teachers to employ cognitive conflict during teaching to promote students' conceptual understanding for better problem solving. Teachers should seek to demystify mathematics so that it does not appear abstract to students as well as contextualizing the content so that it resonates with students lived experiences. Moreover, school administrators should encourage teachers to develop more interest in students' methods and guide them accordingly for better conceptual understanding based on their preferences. In conclusion, mathematics educators should organize in-service training for teachers to gain more skills in cognitive conflict and how it can promote student mathematics learning for quality academic achievement.

5.5 Suggestions for Future Studies

The study recommends further studies to be conducted to obtain data of classroom teaching where cognitive conflicts are analyzed and their role in students' mathematics learning. The study also recommends studies to assess the role of gender and cognitive conflict in mathematics. Also, this study supports the argument by Marker (2020) that studies should be done on how education programs can be enriched with strategies that can improve students' performance in Science, Technology, Engineering, and Mathematics (STEM) careers.

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APPENDICES

APPENDIX I: THEMATIC ANALYSIS PROCESS SHOWING HOW THE THEMES WERE ARRIVED AT

Codes	Examples of participants quotes	Categories	Theme
Seeking teacher(s) help	I consult the teacher to maybe explain the method to me or use another simpler method	Conceptual development through teacher's guidance	A moment to (co)construct one's mathematical meaning
	I do consult the teacher many times and practice more so that I can understand		
	I do consult teachers of mathematics in the school in areas of confusion		
	The ones that are hard and I am unable to solve I go and consult my teacher		
	…when I go to consult I find that the teacher uses a different method from one I know in finding the solution of the sum		
Seeking peer(s) help	…was consulting my friends to solve it	Acquisition of knowledge from peers	
	I consult from peers on difficult areas		

	I go and consult my fellow students who know the concepts		
	I consulted my desk mates and my other classmates		
	Many times I consult my fellow students		
Employ reference materials	I use different books and I check on how the question is solved	Use of reference materials to learn	
	I got the method in a revision book		
	Mostly I borrow books from the library		
Learn individually	I train on my method	Individual commitment and responsibility	
	I practice more and more on it		
	I do keep doing practices continuously until I understand the method		
	I just practice it often by doing some questions		
Group discussion	I do discussions with my fellow students	Skill development through group discussion	
	I do discuss because like this is a group we formed so that we can discuss mathematics together every evening before we go home		

Codes	Examples of participants quotes	Categories	Theme
Challenging method	…with my method I can get the answer but this teacher's method I can't move on and get the answer because I do get stuck from this point	Learners' inability to utilize new method taught	Confusion as a result of teacher's behaviorist stance
	I find difficulties in applying the teacher's method in finding squire roots		
	The problem is as a result of the method taught to be used that happens to confuse me in solving the sum		
	…the teacher insists on the method taught to solve the same problem and I have never used the method taught then I get stuck and miss everything		
	I try what I can but due to instructions on the method to be used I try to follow but I can't see anything		
	…when I try to use the new teacher's method as instructed I felt confused and I asked myself which method should I use		
	…mostly the method that we are sometimes being introduced to use in solving some sums makes me		

	confused		
	the teacher's method was somehow difficult for me because I was used to my method		
	… it is because I am more used to this one so when I was introduced to this it was like of confusing		
Validity of prescribed methods	…when I take my book to the teacher to mark I get that I am not correct because of failure to use the instructed method	Impacts of prescribe methods to learners	
	I fail due to failure to utilize the instructed teacher's method		
	…I was confused because the teacher introduces a new method and stressed that I should use the method to solve the sum as opposed to my method		
	…sometimes when I try to bring out my argument about my method, teacher is like opposes me strongly and I feel disappointed		
	I was told by the teacher that this method although it is correct, it is time-consuming and he stressed that I should		

	use the one taught about power forms that confuses me		
	…when I went to him due to difficulties I have in using the new method he told me that the method I was used to is a primary method but in secondary I must use the one he taught		
Solutions to prescribe methods	…you know in an exam the teacher can specify the method to use, but I try and find what I can do to get a mark	Students struggles with prescribe methods	
	I try to do my method so as to see if it can give the same answer as the instructed method		
	…the teacher's method was difficult and I used mine		
	The instructed method confused me but I took it serious and I started using it to get a mark		
	…after we were taught I got difficulties in understanding the teacher's method but after doing more practice I realized that it is easier and more accurate		
Code	Examples of participants quotes	Category	Theme
Fast	…I was unable to understand because my teacher go fast	Fast concept	A fleeting moment of

explanations	in explaining the concept	explanation as a hindrance to students' conceptual understanding.	magic
	…teacher should explain each sum slowly so that students I can understand		
	…the teacher should explain step by step so that I can understand the concept well		
	…as I try to concentrate I find out that the moment I try to think about what the teacher has done I find out that the teacher has gone to another step		
	…what made me confused in this method I can't be in a position to explain because I did not capture the teacher's explanations		
	Like I seem to understand when the teacher started but after sometimes I get stuck and I get confused due to teacher's faster speed		
	…I find difficulties because without capturing the method of the teacher that is different from mine, and it was explained fast, I find it is stressful		

	The teacher solves it in another way that I was unable to understand because he was moving faster		
	…the teacher did not explain the procedure part by part because he could just get straight to the point		

APPENDIX II: STUDENTS' INTERVIEW GUIDE

1. Please tell me something about yourself? (Probe further)
2. How would you rate your ability in mathematics? (Probe further; e.g., what percentage do you expect to get in KCSE result in mathematics?)
3. Have you ever experienced a moment when the teacher solved a mathematical problem using a method that appeared different from the way you were used to solving such a problem?
4. Have you ever encountered a moment when a student solved a mathematical problem using a method that was different from the one you expected them to use? (If need be, clarify the question: e.g., can you share your experiences about an occasion where you felt say confused about what the teacher was explaining during mathematics lessons?)
5. During mathematics learning, do you get stuck when solving a problem? Name the topic (s) where you have experienced such a problem?
6. Which student gender do you think always get confused during mathematics learning? May you give more reasons for your answer?
7. Is there anything that you have experienced and you need to share with us in this interview about student's confusion in mathematics teaching and learning that we have not discussed?

APPENDIX III: QUESTIONNAIRE FOR TEACHERS'

This questionnaire is designed to assist the researcher to research about cognitive conflict on mathematics teaching and learning in public secondary schools in Embu West Sub-County-Kenya. This study aims at getting your response to cognitive conflict experienced in the classroom during mathematics lessons as a teacher. It is therefore important that you answer the questions provided with honesty and as accurate as possible. Kindly respond to all items in the questionnaire. The information provided here will be used for research objectives only and will be treated with the utmost confidentiality. Please do not write your name or the name of your school on this questionnaire.

SECTION A: Background Information

Please tick whichever you think is appropriate in the following brackets

1. What is your gender?
   Male ( ) Female ( )
2. Which type of school are you teaching at?
   Girls only boarding ( ) Mixed day ( )
   Boys only boarding ( ) Mixed boarding ( )
3. Which age bracket does your age belong to?
   20-29 ( ) 30-39 ( ) 40-49 ( ) 50 and above ( ) years.
4. What is the highest level of formal education that you have completed?
   Diploma ( ) Bachelor's degree ( ) Master's degree ( )

Other specify (……..……)

5. For how long have you been teaching mathematics?
   1-4( ) 5-10( ) 11-15 ( ) above 15 years ( )
6. Have you attended any in-service training in the past three years of your service in mathematics? ……
7. How many mathematics lessons do you teach every week?
   Less than 15 ( ) 15-19( ) 20-25( ) 25 and above ( ).

SECTION B: Cognitive conflict in Mathematics Teaching and Learning

Please answer the following questions

8. Please give your view about the concept of cognitive conflict in mathematics teaching and learning?
   .....
9. How are you utilizing the strategy of induced cognitive conflict to introduce a new mathematical concept to students?
   .....
   .....

In the table below please tick where is appropriate in the boxes provided

NB. Strongly Agree-SA, Agree-A, Not Sure- NS, Disagree-D and Strongly Disagree-SD

No	Items	SA	A	NS	D	SD
1.	I correct students misconceptions					
2.	My students are confused during lessons					
3.	My students have a problem with new concepts					
4.	They always make errors while solving problems					
5.	I always motivate them to concentrate even when they seem to understand nothing					
6.	There are topics I am not comfortable to teach					
7.	Learners' misconceptions make me lose focus of the lesson and present wrong ideas					

Please give your ideas in the following questions based on gender

1. What is the attitude of your students towards mathematics? …….

Give the reason for your answer? ……

2. Which student gender has a lot of challenges with mathematics? .....

Give reason(s) to your answer above……
…….

3. Which student gender do you think experience cognitive conflict highly in mathematics? .....

Give the reason for your answer? ……

4. Please give your idea(s) on how cognitive conflict can be used to improve mathematics learning on the different student?
……
……
……

5. Which topics do students experience cognitive conflict mostly during mathematics learning?

……

……

…….

6. Please give your idea(s) on how such topics should be taught to reduce cognitive conflict in different student gender?
……
……
…….

SECTION C: Teacher Preparedness to Scaffold Mathematics Learning using Cognitive Conflict

Please tick whichever is appropriate in the table below

NB. Strongly Agree-SA, Agree-A, Not Sure- NS, Disagree-D and Strongly Disagree-SD

No	Items	SA	A	NS	D	SD
1	I am ready for my lessons					
2	I apply mathematics to real-life situations					
3	I improvise teaching aids					
4	I solve relevant problems to students					
5	I discuss topics reasonably and confidentially to students					
6	I allow students to participate in lessons					
7	I revise topics with students					
8	I use several demonstrations to explain concepts					
9	I ask students clear and specific questions					
10	I allow students to participate					
11	I give students time to ask questions during the lesson					
12	I give students exercise to do					
13	I revise with students in areas they fail					

APPENDIX IV: QUESTIONNAIRE FOR STUDENTS

This questionnaire is designed to assist the researcher to research about cognitive conflict on mathematics teaching and learning in public secondary schools in Embu West Sub-County-Kenya. This study aims at getting your response to cognitive conflict experienced in the classroom during mathematics lessons as a student. It is therefore important that you answer the questions provided with honesty and as accurate as possible. Kindly respond to all items in the questionnaire. The information provided here will be used for research objectives only and will be treated with the utmost confidentiality. Please do not write your name or the name of your school on this questionnaire.

SECTION A: Background Information

Please tick whichever you think is appropriate in the brackets below

1. What is your gender?

Male ( ) Female ( )

2. Which type of school are you studying at?

Girls only boarding ( ) Mixed day ( )

Boys only boarding ( ) Mixed boarding ( )

Please give your idea on the following questions

1. Which student gender has a lot of problems with mathematics? .....

Give reason(s) to your answer……

…….

2. Do you think boys (girls) experience difficulty in solving mathematics? ....

In the table below please tick whichever you think is appropriate in the boxes provided

NB. Strongly Agree-SA, Agree-A, Not Sure-NS, Disagree-D and Strongly Disagree-SD

No	Items	SA	A	NS	D	SD
3.	Male students solve challenging problems in mathematics through group work easier than female students.					
4.	Female students solve challenging problems in mathematics through group work easier than male students.					
5.	My suggestions are taken seriously in mathematics					
6.	It is possible to show my skills in mathematics					
7.	Male students score higher in mathematics than female students					

8. Name topic(s) you have experienced difficulties in understanding?

……

……

……

9. Explain how you would like the topics to be taught so that you can easily understand them?

……
……
……..

SECTION B: Cognitive conflict in Mathematics Teaching and Learning

In the table below please tick whichever you think is appropriate in the boxes provided

NB. Strongly Agree-SA, Agree-A, Not Sure-NS, Disagree-D and Strongly Disagree-SD

No	Items	SA	A	NS	D	SD
1	I have experienced problems with mathematics questions					
2	My friends help me in solving mathematics problems					
4	My teacher makes mathematics learning boring					
5	My teacher explains the points clearly					
6	There are topics I was not taught well					
7	I am always confused during mathematics lessons					
8	I am not motivated to do mathematics by the teacher					
9	I try to master new math content taught					
10	I do try to improve my mathematics skills					
11	I do feel lost when studying mathematics					
12	I get corrections for my incorrect choices					
13	I concentrate in class and understand nothing					
14	What I learn is always applicable					
15	What I learn encourages me to think					
16	I have problems to do my assignments properly					

SECTION C: Teacher Preparedness to Scaffold Mathematics Learning using Cognitive Conflict

In the table below please tick whichever you think is appropriate

NB. Strongly Agree-SA, Agree-A, Not Sure-NS, Disagree-D and Strongly Disagree-SD

No	Items	SA	A	NS	D	SD
1	My mathematics teacher is always prepared for lessons					
2	My mathematics teacher has good mathematical knowledge					
3	My teacher simplifies mathematics concepts					
4	My teacher comes up with teaching materials					
5	My teacher solves relevant and difficult problems during lessons					
6	My teacher teaches topics well					
7	My teacher encourages us to participate in lessons					
8	My teacher uses clear and specific questions					
9	My teacher uses several demonstrations to explain concepts					
10	My teacher questioning techniques allows us to think deeply					
11	My teacher gives us time to ask questions					
12	My teacher gives us exercise to solve in class					
13	My teacher marks and returns our work regularly					
14	My teacher does corrections in areas we have failed in class					

APPENDIX V: WORK PLAN

Activity	YEAR 2019								YEAR 2020												YEAR 2021								
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S
Proposal Development																													
Proposal Defense & Submission																													
Research Authorization																													
Piloting & Data Collection																													
Data Analysis																													
Publication Development																													
Thesis Development																													
Thesis Submission & Examination																													
Thesis Defense																													
Thesis Corrections																													
Graduation																													

APPENDIX VI: BUDGET

S/N	Items	Quantity	Amount in (KShs)
1.	Field notebook	2 @ at 80/-	160
2.	Pens	10@ at 20/-	200
3.	Transportation		10,000
4.	Accommodation		22,000
5.	Pilot		3,000
6.	Research Project Permit	1 copy	2,000
7.	Questionnaires printing and photocopying	398	4821
8.	Printing and binding of proposal	2 @ at 165	330
9.	Printing and binding of the final project report	2 @ at 440	880
10.	Publishing of the Project		20,000
	Total cost		63,391

APPENDIX VII: RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

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Date of Issue: **03/February/2020**

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