

Science and Mathematics Education Centre

**Cognitive Acceleration in Mathematics Education in Tonga: Effects
on students' mathematics achievement, motivation, and self-
regulation**

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**This thesis is presented for the degree of
Doctor of Philosophy
of
Curtin University**

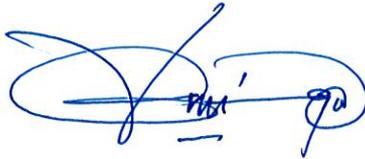
May 2017

Declaration

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This thesis contains no material which has been accepted for the award of any degree or diploma in any university.

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Abstract

There are three major issues experienced by many secondary schools in Tonga, namely, the increasingly poor performance of students in mathematics, the low level of students' engagement in mathematics, and the increasing number of students who enter high schools with insufficient skills in mathematics. The current mathematics curriculum and teachers' teaching skills do not have the capacity to provide an effective learning environment so that students could improve their reasoning skills and mathematical understanding. Therefore, there is an urgent need for innovative teaching and learning approaches that have the potential to contribute to solving these issues in secondary schools in Tonga.

The Cognitive Acceleration in Mathematics Education (CAME) program is an innovative teaching approach based largely on Piaget's cognitive development theory and the socio-cultural psychology of Vygotsky. The CAME program involves the application of some special learning and teaching procedures in mathematics classes which results in students attaining higher levels of cognitive development more quickly than if they had not been presented with these procedures. The materials for the CAME program were adapted and implemented in Tonga over the course of one school year (March – November) with the main purpose of the research to investigate the effects of the CAME program on Tongan Form 2 (Year 8) mathematics students' achievement, learning motivation and self-regulation, and the teachers' teaching practices.

A quasi-experimental with non-equivalent comparison groups design was used to provide responses to the research questions. The researcher developed two instruments - Numeracy Reasoning Task 1 (NRT1) and Numeracy Reasoning Task 2 (NRT2) – with 20 items each which were administered to 338 students in the experimental and the comparison groups as a pre-test (NRT1) and post-test (NRT2) to explore the effects of the CAME program on students' achievement. The experimental group post-test performance was significantly higher than the post-test performance of the comparison group students, suggesting the positive impact of the CAME program in the Tongan Form 2 mathematics students. The results of independent t-tests analysis between the

experimental group and the comparison group students' performance as well as the results of the paired sample t-test analysis between the NRT1 pre-test and the NRT2 post-test in each group indicated that the CAME program was more effective with regards to students' understanding and achievement compared to the traditional instruction in Tonga Form 2 mathematics topics.

The adapted Students' Adaptive Learning Engagement (SALE) instrument was administered to 338 students in the experimental and comparison groups as a pre-test and post-test to investigate the effects of the CAME program on students' learning motivation and self-regulation. The independent t-test analysis results between the means scores of the experimental and comparison groups showed that there were statistically significant differences in all the four scales of the SALE instrument with students in the experimental group having higher mean scores than the comparison group. The results suggest that the CAME program was effective in improving the Tongan Form 2 students' learning motivation and self-regulated learning. The analysis of the teachers' interviews revealed that the CAME program had positive effects on the experimental teachers' teaching pedagogies and the teachers' behaviours when they interacted with their students.

This study has made a distinctive contribution to the Tonga Form 2 mathematics curriculum and mathematics teachers' teaching pedagogy, being the first study in Tonga to investigate an approach that promotes the development of mathematical thinking skills to improve students' achievement and learning motivation and self-regulation. The study revealed that teaching higher order thinking is appropriate and possible for the Tongan students no matter what levels of thinking ability they have. Also, this study showed that a specially designed professional development program could contribute to improving the teachers' teaching practices which became more student-centred in terms of how they communicate and interact with the students. Although the CAME intervention was the focus on the Tonga mathematics Form 2 level, the teaching strategies and theories could be applied to the teaching and learning of other class levels, subjects, and the primary school students in Tonga.

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Dedication

I dedicate this doctoral thesis to my parents, Vainima Finau and Ana Paongo Finau; to my wife, Ana Siale Finau; to my son, Teukava Finau Jr, and to my high school science and mathematics teacher, Kilupi Tukutukunga, who inspired me to become a special mathematics and science teacher.

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Chapter 1 Introduction

1.1 The research problem

Three major issues experienced by many secondary schools in Tonga are the increasingly poor performance of students in mathematics, the low level of students' engagement in mathematics, and the increasing number of students who enter high schools with insufficient skills in mathematics (Manu, 2005; Ministry of Education and Training, 2014; Pohiva, 2014). According to Thaman, Matang, Pene, Rainey, and Alcorn (1998), some schools in Tonga and other Pacific countries have not prepared students to the extent that most people in those countries expected. They continued, by stating that "our schools are increasingly turning out more failures than successes" (p. 8). Earlier, Tatafu, Booth, and Wilson (2000) claimed that fewer than 10% of students in Tonga who start school in Form 1 (Year 7) will be successful in obtaining a Tonga School Certificate (TSC) in Form 5 (Year 11) at the age of 16. In later research, Vivier (2013) summed up this assumption and conducted a study in Tonga aimed to provide an overview of the factors that affect the learning of Tongan students. Her study claimed that approximately 62.7% Tongans over the age of 15 years old had some secondary education but only 26.2% had acquired a secondary qualification. Most of the students were 'drop-outs' (early school leavers) for various reasons, including learning difficulties, lack of interest in what they were doing in class, teacher's pedagogical approaches that did not suit the students' learning styles, and resistance to the school's rules. Although her results were not the same as those of Tatafu et al. (2000), the issues of poor performance and low level of students' engagement in mathematics and other subjects are an existing problem.

As a high school mathematics teacher in Tonga from 2002 to 2012, I was aware of these issues and that they had become major problems during my teaching experience. The students were diverse in many ways. They varied in cognitive, physical and social development and abilities. They came from different socio-economic background and family structures. Their interests and learning styles also varied. These diversities in students' background presented difficulties for me as a teacher to teach and to facilitate their mathematics skills to meet everyone's expectations. In fact, the current mathematics curriculum and teaching skills did not have the capacity to provide an

effective learning environment so that students could improve their reasoning skills and understanding. As a result, most students became disengaged and lost their interest in learning mathematics which led to low achievement and poor performance in mathematics. Some of these students decided to be absent from their mathematics classes because they are no longer interested in learning mathematics (Manu, 2005; Ministry of Education and Training, 2014). Indeed, there is an urgent need to develop new pedagogies in teaching mathematics that can improve students' thinking ability as well as encourage them to learn and be engaged in learning mathematics. In other words, new or innovative teaching and learning approaches that have the potential to contribute to an improvement in Tongan secondary school students' mathematics understanding and achievement are needed.

1.2 Related research

Many studies have shown that students' engagement and academic achievement can be influenced by their learning motivation and self-regulation toward the subject matter (Wong & Wong, 2009). For example, Attard (2011) who conducted a study in Australia argued that students who are disengaged in learning limit their potential to understand their learning experiences leading to lower academic performance. A similar study conducted by Otunuku, Brown, and Airini (2013) was directly related to Tongan students who study in secondary schools in New Zealand. The study investigated how students' attitudes, including self-regulation and motivation, influenced their achievement. The findings showed that students' motivation, self-efficacy and self-regulation as well as beliefs about assessment, learning, and teaching have a statistically significant impact on academic achievement. These authors posited that Tongan students' learning self-regulation, motivation, and beliefs do matter for their learning outcomes. In addition, the study also found that there is a strong teacher effect contributing to Tongan students' misunderstanding of their real academic ability. According to Otunuku and Brown (2007), this issue exists because most secondary school teachers in Tonga and New Zealand have low morale and motivation in the way they teach in the classroom and these likely contribute to students' poor performance. The study suggested a change in classroom practices to help students adopt adaptive attitudes which may lead to higher levels of students' academic performance.

Previous studies related to cognitive development highlighted the importance of improving students' cognitive ability and thinking skills as a pathway for achieving better academic performance (Adey & Shayer, 1990; Adhami & Shayer, 2007; Dullard & Oliver, 2012; McLellan & Adey, 1999; Venville & Oliver, 2015). These studies highlighted the positive influence of a well-designed curriculum and lesson activities as a way to improve students' learning and thinking skills. For example, in a study conducted in England, McLellan and Adey (1999) emphasized that without students' understanding the concepts of the learning activities, they become disengaged in their learning which in turn leads to classroom behavioural problems and low academic achievement. In support of this view, in later work Adhami and Shayer (2007) argued that if the learning activities are not interesting to the students because of the mismatch between curriculum demand and students' cognitive ability, the students will not learn those activities. Here, Adhami and Shayer emphasized the importance of having well-designed lesson activities within a well-constructed mathematics curriculum in guiding and teaching the students. Their study of the Cognitive Acceleration in Mathematics Education (CAME) with students in England highlighted these ideas and improving students' academic achievements and reasoning skills (see Chapter 2 for more details of their study).

Looking at the results and findings of previous studies, it is wise to reconsider their strategies and theories in developing mathematical teaching and learning approaches which may promote better learning performance outcomes for students of Tonga. In fact, Tongan students perform poorly in mathematics because they are unable to adequately handle information that is related to concepts and procedures necessary for them to communicate mathematics ideas and to be involved in mathematics problem solving (Fasi, 1999; Manu, 2005; Pohiva, 2014).

1.3 Background of the study

Tonga's educational system was initially modelled after that of England, but it has since evolved to become more compatible with Tonga's social and economic structure (Ministry of Education and Training, 2014). Religion is deeply integrated in Tongan society, and in the education system as well, with the result that the Tongan secondary educational system relies heavily on a range of Christian religious schools. Approximately 28% of the student population attends government schools and the

remaining 72% attends church schools (Vivier, 2013). Different from many other education systems where some private schools are among the best schools, the Tongan government schools are regarded as the best secondary schools in the country because they always select students with the highest scores in the Secondary School Entrance Examination (SSEE). The students with lower scores in the SSEE enter the church-affiliated high school of their choice (Uata, 2002).

In recent decades, there has been a growing concern over the low-level mathematics performance in Tongan secondary schools (Fasi, 1999; Manu, 2005). The Tonga National Examination Unit (TNEU) has reported that students perform poorly in mathematics compared to other subjects. For example, in the 2013 Tonga School Certificate (TSC) examination for 16-year-olds, only 48% of students passed in mathematics compared to 86% in accounting, 78% in economics and 68% in English (Ministry of Education and Training, 2014). The mathematics chief examiner's report indicated that students tend to do well on questions that require simple recall of information but have difficulties in answering questions that demand an understanding and application of mathematics concepts (Ministry of Education and Training, 2014).

Many aspects of Tongan education are seen as contributing towards students' poor performance, including inadequate teaching and learning resources (Ministry of Education and Training, 2014), a shortage of qualified teachers to teach mathematics (Tatafu et al., 2000), students' low socioeconomic circumstances (Uata, 2002), an examination system that reinforces rote learning, and the mismatch between students' cognitive ability and the cognitive demands of the school mathematics curricula (Pohiva, 2014).

In an effort to improve students' performance in mathematics, the Ministry of Education in Tonga has developed several curricular modules that place emphasis on teaching mathematics thinking skills. Yet, teaching mathematics thinking skills has been found to be problematic in many instances, especially for skills such as controlling variables, interpreting data, conceptualizing and problem solving (Ministry of Education and Training, 2014; Pohiva, 2014). Just as is the case in many parts of the world, Tongan mathematics educators are looking for approaches that promote the development of mathematical thinking skills to improve students' mathematics performance.

1.4 Rationale for the study

As the result of the changes and issues described above, in 2011, all mathematics teachers at all levels throughout Tonga were required by the Minister of Education to reform their instructional practices and engage in professional development support. The Tonga Ministry of Education with the help of the New Zealand government and the University of the South Pacific (USP) conducted six months (June – November) professional development training program for mathematics teachers at the secondary school level. This professional development (PD) program was designed to revise the teachers' teaching approach in mathematics and to seek better teaching options that can work for their students in their various classrooms. The Tonga Ministry of Education has not yet released the formal report regarding the effects of this PD program on teachers and students. However, in 2013 some church secondary schools (schools that enrolled students not accepted by government secondary schools) stated that teaching and learning mathematics in their schools is still problematic in many instances (Ministry of Education and Training, 2014; Pohiva, 2014). According to some principals of these schools, most students entering their schools have inadequate mathematics skills and could not communicate mathematically in either whole class discussion or their group work activities. Principals further suggested an urgent need for new or innovative learning strategies that could help improve the learning of these inadequately prepared students in Tonga.

In searching for a solution to this problem in Tonga, the researcher came across the studies conducted by Adey and Shayer (1993, 2002) and Shayer and Adhami (2007) with high school students in England that focussed on similar problems to those experienced by secondary school students in Tonga. According to their studies, these authors emphasized the point that these students cannot be taught effectively by the school's normal mathematics or science curriculum with the usual teachers' teaching strategies. In fact, there is a mismatch between the demands of the standard curriculum of these two subjects with the levels of cognitive ability of the students and that is why these students seemed to disconnect and be disengaged from learning. Consequently, special teaching strategies with special well-designed lessons could help minimize the mismatch through accelerating these students' cognitive abilities and understanding of the subject matter. In the case of mathematics, Adhami and Shayer (2007) developed a new cognitive acceleration program known as 'Cognitive Acceleration in

Mathematics Education (CAME)' as a possible solution to improve the mathematical understanding and thinking skills of the students. Details of the CAME program are presented in Chapter 2 of this thesis. Also, Shayer and Adhami (2007) reported the long-term effects of the CAME program in improving the academic achievement and reasoning skills of the English students who participated in this CAME program intervention.

To address the issues of inadequate mathematical preparation, this study adopted the CAME acceleration program and evaluated its effectiveness in terms of Tongan students' academic achievement as well as students' learning motivation and self-regulation in mathematics. By adopting this CAME program in Tonga, the researcher intended to gain an understanding of whether or not the development of cognitive ability of secondary school students in Tonga can be accelerated and to what extent that development can effect students' achievement, learning motivation, and self-regulation. This research could, for example, identify some ideas why secondary school students in Tonga had problems dealing with questions that require application of knowledge and abstract ideas. The CAME approach consists of a set of lessons, called '*Thinking Maths*' (Adhami & Shayer, 2007), with 30 activities designed on the psychological insights from Piaget and Vygotsky. These CAME lessons take a Piagetian view of what is implicit in mathematics and incorporate this view into lessons conducted according to the Vygotskian view of psychological development. In other words, "the move from concrete to formal operational thinking is derived from Piagetian psychology but the idea that this transition should be made possible for more students by appropriate teaching draws on the work of Vygotsky" (Goulding, 2002. p. 105). More discussion on these two theorists' approaches are explained in Chapter 2.

1.5 Research Aims and Research Questions

This section includes the Research Aims that motivated this study and a brief discussion of the Research Questions which serve to drive the study.

The Cognitive Acceleration in Mathematics Education (CAME) program hypothesizes that it is possible to accelerate or facilitate students' cognitive abilities if the zone of proximal development can be identified properly. Consequently, one aim of the CAME program intervention in Tonga was designed to improve students' thinking

processes by accelerating their progress toward higher-order thinking skills or what Piaget termed ‘formal operations’. The other aim of the CAME program was to improve students’ motivation and self-regulation in learning mathematical concepts in the main topic areas of the Tonga mathematics curriculum. As Breen, Cleary and O’Shea (2009) argued, if students’ intelligence, learning motivation, and learning self-regulation are combined, they will influence the students’ behaviour when presented with difficult or unfamiliar tasks.

Consequently, this study was designed to answer these following three Research Questions;

- 1 To what extent does the CAME program change Tongan Year 8 (Form 2) students’ academic achievement in mathematics?
- 2 What are the Year 8 (Form 2) students’ motivation and self-regulation levels regarding their participation in the learning of mathematics in the CAME program?
- 3 What are the teachers’ perceptions of their participation in the CAME intervention program?

These research questions were designed to investigate the effects of the CAME intervention program on students’ learning and teachers’ teaching by investigating students’ classroom engagement and their mathematics performances. In addition, the investigation also attempted to identify the weaknesses as well as the strengths of the CAME intervention in the context of Tonga secondary schools. The findings of this investigation could be useful for the application of this program model in the future and to ascertain the strengths that can be sustained and the weaknesses that need to be taken into account in future plans to implement the program in the Tonga Education system.

1.6 Research Methodology

This section briefly describes the research design employed in this study. Also, it gives a brief explanation of the sample, the methods of data collection, and also the data analyses. Further details are provided in chapter 3.

1.6.1 **Research Design**

In order to evaluate the effectiveness of the CAME program on Form 2 (Year 8) Tongan students' learning, the participants of the study were divided into two groups. The first group was the experimental group which learned mathematics under the CAME program, and the other group was the comparison group which learned mathematics without access to the CAME program materials. Due to the impossibility to randomize the participants of this study to either experimental or comparison groups, this study with existing class groups chose a quasi-experimental design as a suitable research design for this study to address the Research Questions.

The quasi-experimental design used the collection of both the quantitative and qualitative data from the two groups. Quantitative and qualitative data were integrated within this study to evaluate the effectiveness of the CAME program and to provide an insight into any problems that might exist. More details of this research design are explained in Section 3.1 of Chapter 3.

1.6.2 **Sample selection**

The samples included in this study were Form 2 mathematics students and teachers in four secondary schools in Tonga. These four secondary schools were all church schools where the majority of the students were not accepted by the government secondary schools because of their low marks in the SSEE in primary school. With these four selected secondary schools, three were treated as the experimental group where the CAME program was implemented, and one school was treated as the comparison group with no access to the CAME program. Two hundred and nineteen students and 7 teachers in the experimental group and 119 students and 4 teachers in the comparison group participated and completed the CAME program intervention and research comparison.

1.6.3 **Data Sources**

Three instruments were used in this study; Numeracy Reasoning Task 1, Numeracy Reasoning Task 2, and the Students' Adaptive Learning Engagement (SALE). The NRT1 and NRT2 were constructed by the researcher as instruments to measure the effective of the CAME program in students' achievement. A pre-test (NRT1) was

administered to assess students' conception and understanding of Form 2 Mathematics topics prior to the CAME intervention. At the end of the CAME intervention, a post-test (NRT2) was used to gauge students' achievement. These two tests were adopted in this study because the tests that were developed by Shayer and Adhami in the CAME project implemented in high schools in England were not accessible for the researcher of this study.

The SALE instrument (Velayutham, Aldridge, & Fraser, 2011) was modified then translated into the Tongan language to accommodate the language needs of some participants. Following the translation by the Tonga Service Centre translation department, two English teachers from Liahona High School (LHS) checked the accuracy of the translation and made sure that the original meanings of the items had not been lost. Details of this instrument is described in Section 3.4 of Chapter 3.

Quantitative Methods

The modified SALE instrument (both English and Tongan) was administered at the beginning and the end of the CAME intervention as a pre-test and post-test to gauge the students' learning motivation and self-regulation in mathematics. The items of the SALE instrument are grouped in four scales; Learning Goal Orientation, Task Value, Self-efficacy, and Self-regulation. The first three scales (Learning Goal Orientation, Task Value, and Self-efficacy) are considered as three aspects of motivation, and they are theoretically linked (Velayutham et al., 2011; Zimmerman, 2002). Hence, these three scales were used to gauge the students' learning motivation. The fourth scale (Self-regulation) was used to assess the learning self-regulation of the students during their participation in the CAME program intervention.

The students also completed the NRT1 prior to the CAME intervention and NRT2 at the end of the CAME intervention. Both the NRT1 and NRT2 have 20 items each and were all adopted from the past examination papers of the Tonga Form 2 Mathematics Common Examination (Form 2-MCE) of the government secondary schools. As this study evaluated the effectiveness of the CAME program on students' achievement, these two instruments were used to provide the data for that assessment. More information about these three instruments and the quantitative data will be found in Section 3.4 of Chapter 3.

Qualitative Methods

The qualitative methods used in this study involved classroom observations and semi-structured interviews with both students and teachers. Qualitative information was used in seeking explanations and patterns of students and teachers responses identified through statistical analysis of the quantitative data collected. Sixteen students (4 students from each school) and 7 teachers (5 teachers from experimental schools and 2 teachers from the comparison school) were purposely selected to participate in the interviews. Details of these interviews are described in Section 3.4.3 of Chapter 3.

1.6.4 Data Analyses

The quantitative and qualitative data were prepared separately for analyses. The quantitative data were analyzed using SPSS software version 22 (Pallant, 2013). An independent t-test was used to compare these two groups, and tests of statistical significance were used to investigate the differences in students' performance in the experimental group and the comparison group. Also, a paired sample t-test was conducted in each group to acquire the performance of the students in the post-test compared to their performance in the pre-test.

The qualitative data of the students and teachers' interviews were fully transcribed and prepared for coding, themes selection, and analysis. The process of coding the transcripts were in two phases, first, the researcher manually identified the codes and themes through repeated listening to the audio recordings as well as repeated reading of the transcripts. In this way, themes and ideas were identified that were relevant to the research questions and were used to confirm or provide insight into the quantitative data as well as identify themes and ideas that disconfirmed the quantitative data (Creswell, 2012). The researcher then used triangulation and member-checking to enhance the accuracy of the analyses. In the second phase, the researcher used the NVivo 10 software to analyze the interviews data and help clarify the accuracy and unbiased nature of the analyses done in phase 1 (Castleberry, 2014).

1.7 Significance of the study

This study is noteworthy within the Tonga Education system because this designed cognitive acceleration program could help reverse the situation of low achievement in

mathematics by engaging teachers in professional development, designed lesson activities and underlying theoretical principles. The CAME professional development emphasizes the role of the teachers in developing students' mathematical reasoning ability rather than technically providing fragmentary teaching of solving and calculation procedures. Details of the CAME professional development that was conducted in Tonga are explained in Section 3.3 of Chapter 3.

There have not been many studies or literature reviews about mathematics education in the context of Tonga. The only related studies are available such as that by Koloto (1995) conducted a study for her doctoral degree entitled Estimation in Tonga while Manu (2005) investigated the role of code-switching in mathematics understanding in the Tongan classroom. Fasi (1999) investigated the effect of bilingualism and learning mathematics in English as a second language in Tonga. Together, these are the only studies that have formed the basis of the literature specifically relating to mathematics education in the Tongan context. Therefore, there is a great need for research in mathematics education in Tonga, especially regarding mathematics teaching, students' learning and the learning materials.

Likewise, this study is significant because it is designed to generate valuable information for the school itself, the Tonga Ministry of Education, policy makers, as well as the mathematics teachers and educators in Tonga. The possible future use of this program in the Tongan context is anticipated. Its effect and results can serve to enhance teaching practices and students' learning in the future.

1.8 Limitations

During the implementation of this study, the researcher identified a number of limitations that could have an impact on the outcomes of this study. Firstly, the data of this study comes from only four secondary schools in Tongatapu, the main island of Tonga. So it may be inappropriate to generalize the findings to the rest of the secondary schools in Tongatapu or the outer islands of the main island of Tonga.

The second limitation that could influence the results of this study is that the researcher conducted the interview of both students and teachers. This may also affect some of the participants' responses.

The final limitation is concerned with duration of the CAME intervention in Tonga and the number of CAME lessons that selected for the study. Due to limited time of this study, the CAME intervention was designed for eight months compared to similar studies of the CAME intervention that were conducted over two years. However the CAME intervention over two years consisted 30 CAME lessons (selected from the ‘*Thinking Maths*’) and it conducted with one lesson every two weeks during school term (see Section 2.4.2 of Chapter 2). Whereas this CAME intervention in Tonga used only 16 selected CAME lessons and conducted with one lesson per fortnight for two semesters in one year. So the shortened period of the intervention and reducing the number of CAME lessons may affect the results of the study.

1.9 The organization of the Thesis

This thesis has five chapters followed by the references and appendices.

The first chapter presents a brief overview of the research problem, the background, the rationale, and the research aims of this study. Also, an overview of the research methodology, significance, and limitation of the study are discussed.

Chapter 2 contains the literature review relevant to this study. The literature review describes studies pertaining to the CAME program, including an examination of the historical background of the program, the theories that influenced in the program, and the characteristics of the CAME approach. In particular, research relating to the cognitive acceleration aspects is discussed, including the results of the previous studies, the CAME structures, and the changes that have occurred in the CAME program that have been offered worldwide. Some literature relating to learning motivation and self-regulation as it links to students’ achievement are also described.

Chapter 3 deals with the methodology used in the study. This chapter contains the research design, participants of the study, and includes data collection, data analysis, and details of the instruments with their validity and reliability.

Chapter 4 reports on the quantitative and qualitative data analysis results for each Research Question.

Chapter 5 contains a discussion and summary of the major findings, the limitations of the study, matters for further research, and a discussion of the implications of the study for mathematics teaching and learning, particularly for Tonga school administrators and for mathematics curriculum designers.

Chapter 2 Literature Review

2.1 Introduction

This chapter focuses on a review of the literature relevant to the intervention study that used the Cognitive Acceleration in Mathematics Education (CAME) program as a medium for improving students' learning in mathematics at the secondary school level. The literature review included several studies which are similar to the aim of the CAME program.

After this overview of the chapter, Section 2.2 reviews the literature related to cognitive development theories, particularly the theories of cognitive development of Piaget and Vygotsky that are used in-depth in the CAME program. Section 2.3 describes the historical background and Section 2.4 describes the development of the CAME program including related studies such as the CASE program. Section 2.5 highlights the theoretical base and pedagogy of the CAME program that emerged from a combination of the cognitive development theories of Piaget and Vygotsky. Section 2.6 reviews the literature related to learning motivation and self-regulation and how they are related to students' achievement and understanding. Finally, Section 2.7 is the summary of this chapter.

2.2 Cognitive Development

Generally, cognitive development involves processes that enable students to gain information about their surrounding environment such as reasoning and problem-solving (Goswami, 2011). Garton (2004) described cognitive development as a term where perception, language, memory, reasoning, problem-solving and learning are linked together and is associated with the organisation and use of knowledge. Adey and Shayer (1994) and Adey (2005) described cognitive acceleration as the possibility of the development of students' general thinking ability to process information. They continued by stating that cognitive development is a term that describes the effectiveness and power of students' general thinking abilities from conception to maturity under the combined influence of genetics, maturation, and experience (Shayer and Adey, 2002). From his studies, Plomin (2012) found a substantial genetic

correlation between intelligence and cognitive change in childhood and in old age. Similarly, Price, Oliver, and McGrane (2015) emphasised the point that as children mature, their cognitive and working memory increases such that older children can hold more bits of complex incoming information than most the younger children. Theories of cognitive development are based on their constructed models. Two main theories of cognitive development are discussed in this study: Piaget's stage theory of cognitive development and Vygotsky's model of cognitive development where he gave much emphasis on the role of social interaction and language. The position of these two theories with respect to their defining cognitive developments are also outlined.

2.2.1 Piaget's theory of cognitive development

Many books on cognitive development studies acknowledge the work of Jean Piaget (1896 – 1980) with his outstanding contribution to modern cognitive development psychology. He spent much of his life studying and developing a cognitive development theory from babyhood to maturity. Parts of his theory has been criticized by many scholars. For example, Piaget's theory emphasised physical environmental factors where the teacher needs to prepare those physical environments to engage students' attention and interest. However, Bruner criticised Piaget for failure to consider the student's prior experiences and insightful teaching (Sutherland, 1992). Bruner also criticised Piaget regarding his theory claiming that it is impossible to accelerate the learning of the students to move faster through the stages. Other scholars criticised Piaget's stages theory of development and argued that the rate at which students move through the stages vary in different cultures depending on the quality of environmental stimulation (Goswami, 2011; Sutherland, 1992). Despite these criticisms, Piaget's ideas and theory of cognitive development still influence and challenge modern developmental psychology.

In the 1960s, Bruner and other American educators and psychologists discovered that the works of Piaget played a significant role and had a powerful influence in replacing the behaviourists' traditional theory of learning. The behaviourists' theory claimed that students learn most efficiently when they are given lesson material devised by an expert teacher and a curriculum planner. Students are to be presented with some task and work through the activity and then asked a question to test whether or not he or

she has mastered the concept. If the answers were wrong, the student is presented with a remedial lesson then go through the questioning process again until he/she answers it correctly; then the student moves on to the next task.

In contrast, Piaget argued that children's learning is a qualitative breakthrough when changes occur as a result of the adaptation of existing cognitive structures. So whether the child's answer to the question is right or wrong was not the issue as long as he or she was building up the understanding of his or her environment (Sutherland, 1992). In comparison, the behaviourists were interested in the act of learning at a particular moment in time, whereas the Piagetians' interest was in cognitive development from birth to adulthood. Piaget's ideas that are widely accepted include the child being active and information seeking, constructing his or her own understanding, and the notion of cognitive development being a result of genetic inheritance, maturation and the surrounding environment (Garton, 2004; Mbanjo, 2003; Sutherland, 1992).

Piaget's approach to his work was to investigate how individuals acquire knowledge and where the knowledge comes from. Piaget's first intention was to develop a theory of the structure of knowledge rather than a theory of the structure of mind (Shayer & Adey, 1981). Therefore initially he observed and interviewed his own children and then extended his studies to other children of his hometown, Geneva. From his investigations, he created a theory about the development of cognition in children where he argued that the development of children's cognition occurs through a series of different stages of thinking, each qualitatively different from the other (Sutherland, 1992). Siegler (1998) who restudied Piaget's theory from an information processing approach stated, "his theory addresses topics that have been of interest to parents, teachers, scientists, and philosophers for hundreds of years... Piaget's theory is one of the significant intellectual achievement of our century" (p. 25).

The work of Piaget that has received most attention is the theory of cognitive developmental stages which was later adapted by Bruner in developing his stage theory of cognitive development which contains three stages: "enactive – learning is by doing; iconic – learning is by means of images and pictures; and symbolic – learning is by means of words or numbers" (Sutherland, 1992, p. 61). Piaget postulated that the birth to maturity of the child's thinking undergoes qualitative changes, which occur in four distinctive stages. The stages are in hierarchical order, each stage building upon and

incorporating the previous stage. The attainment of each stage requires a fundamental restructuring on the part of the child's cognition. Piaget described four broad stages of development namely; sensorimotor (from birth to 2 years), pre-operational (2 to 7 years old), concrete operational (7 to 12 years old) and formal operational stage (12 years old to adulthood).

In the sensorimotor stage, the child explores the world through acting on objects, and in the pre-operational stage, the child can act on objects mentally without having to act on them directly. At this stage, the child starts to acquire the semiotic functions of language and imagery and can explore the world through symbolic play, imagination, and imitation. For the concrete operational stage, the child can transform knowledge into an organized network. From the pre-operational to the concrete operations stage, there is a shift from relying on perception to reliance on logic. However, the child's cognitive system is still limited by the need for concrete objects to support problem-solving. In the final stage, the formal operation stage, the child can think through more abstract concepts or hypotheses and can conceive of some new ideas from it. In this stage, deduction is now used. For example, in mathematics, the student can deduce a follow-up proposition from a general abstract proposition that is presented to him or her. This process replaces the inductive reasoning of the concrete operational stage.

Adaptation – The theory of learning

Piaget emphasized that learning is a process of adjustment to the environment where intelligence is an adaptation (Sutherland, 1992). He describes the process of construction in cognitive development in terms of 'adaptation,' that is an organism modifies its behaviour for better survival in the environment. According to his theory, adaptation is seen to occur through the interaction of two corresponding processes of 'assimilation' and 'accommodation.' Assimilation is the process where the student organises information that is provided by the environment so that it can match with his or her cognitive structures or ability. Accommodation happens when the information from the environment cannot be easily assimilated in the student's cognitive structures. In other words, assimilation refers to organizing the new experience within the mind whereas accommodation involves adjusting the mind to new experience. This brings about the concept of cognitive conflict, a term used to explain when a student "cannot apply his or her existing concepts to solve a problem, and thus in confronted with a

situation that motivates the learning of new concepts” (Chow & Treagust, 2013, p. 47). According to Piaget’s theory, in order to resolve this conflict, the cognitive structure of the student changes so that the new information can be assimilated. Once the new information has been assimilated, the cognitive structure is said to have been accommodated to the new information. The process of accommodation then leads to reorganisation of the student’s cognitive structure where he or she can cope with more complex concepts. At any stage of cognitive development, accommodation or assimilation dominate for a while and then one is replaced by the other. Once these two processes have occurred, the child’s equilibrium has been reached at that stage; that is, the child is operating at full efficiency for that particular stage.

Piaget’s theory has been influential in its contribution to learning and teaching to enhance thinking. The most notable of his contributions to learning and teaching is that children are active learners. Piaget posited that children better construct their understanding when they interact with the physical world. His idea shifted the teaching strategies from teacher-centered to student-centered. With this teaching approach, assimilation and accommodation highlighted the importance of starting the learning process from students’ current level of understanding and then incorporating cognitive conflict to extend their knowledge.

2.2.2 Vygotsky’s cognitive development theory

Vygotsky was born in 1896 in Russia and died in 1934. Most of his theories became available to the world in the early 1960s when his research was translated from Russian into English. He lived in the same era as Piaget and shared his views of a child constructing meaning from interaction with the environment. However, Vygotsky was one of the first significant figures to criticize Piaget’s ideas by introducing the influence of social-interactive perspectives, arguing that a child’s cognitive development cannot be considered in a social vacuum (Garton, 2004; Sutherland, 1992).

Vygotsky posited that children’s thinking was limited due to certain higher cognitive functions such as awareness of mental operations which are not available until adolescence. Similar to Piaget’s theory, Vygotsky viewed development as involving qualitative or revolutionary changes in children’s thinking as a result of adaptation of

existing cognitive structures to the new knowledge and environment as they grow from infancy to adolescence and adulthood. However, Vygotsky's theory differs from Piaget's theory in the sense that development is said to occur by cultural transmission, a mechanism for passing the knowledge and skills of the older generation (or more capable peers) to the new generation (or less capable peers) through mediation and active participation. Generally, his theory gave much more emphasis to the role of social interaction and language in cognitive development than in Piaget's theory. Although these two theorists on cognitive development and learning were seen as being contradictory in some ways, the developers of the *Thinking Maths* intervention have long held the view that both perspectives inform the nature of pedagogy and impact not only on learning, but also on cognition and development (Shayer, 2003).

Vygotsky's cognitive development theory focused on three main elements namely; (1) cultural development, (2) the zone of proximal development (ZPD), and (3) the role of language (Sutherland, 1992; Vygotsky, 1981; Zaporozhets, 2002).

Cultural Development

Vygotsky believed that all the higher mental functions such as the structure of perception, memory, emotion, thought, language, problem-solving and even behavior development occur in a social and cultural context (Vygotsky, 1981; Zaporozhets, 2002). Also, he claimed that cognitive and language development could develop in children only when social and cultural contexts are involved (Garton, 2004).

Vygotsky emphasized that learning is the transfer of responsibility for the achievement of desired knowledge or goal from an expert to less expert through collaborative interaction (Garton, 2004). That responsibility transfer includes planning and monitoring efficient and effective strategies for accomplishing success, and demonstrating mastery of all aspects of the task. As children interact with more capable peers or adults, they internalize external and social activities and make them part of their mental structures. The emphasis on social interactions and mental processes depends on the forms of mediations involving psychological tools, individual activity and interpersonal activity (Vygotsky, 1981). Psychological tools are seen to direct the mind and behaviour of children and hence language is the key tool for thinking. The mental function firstly exists in social context then the child internalizes those concepts

inside his or her mental structures. Indeed, acquisition of language skills plays a vital role in the evolution of concepts because it provides new perceptions, a new variety of memory and new thought processes (Sutherland, 1992).

Zone of Proximal Development (ZPD)

With regard to the social interaction and internalization of the adults' mediation, the notion of 'zone of proximal development' (ZPD) arises. Vygotsky (1978) defined this notion as the distance between a child's actual developmental level as seen when the child is solving problems "under adult guidance or in collaboration with more capable peers" (p. 86). According to Vygotsky, there is a difference between what the child knows and what the child could potentially know under the appropriate help of another capable person. However, every child has varying capacities for development of their potentials, which means the more capable or expert person's knowledge or skill should be above the potential level boundary of each child's ZPD. In this case, the help provided by this expert would be beyond the child's "sphere of readiness" (Ellis & Barkhuizen, 2005, p. 233). Furthermore, development of knowledge or skill within the child will not occur if too much help is provided (i.e. not giving the child the opportunity to develop the ability to act and think independently) or if the task is too easy (i.e. the concepts are already within cognitive reach of the child). In term of the relationship of the learner and the expert, Walker (2010) described the zone of proximal development as a relation or affective zone. It is a socially mediated zone where the teacher with student or student with student trust each other in sharing and discussion.

This zone measures the student's learning potential and requires an effort to achieve the desired knowledge. In fact, this is the region wherein cognitive development takes place through collaboration between the students and teacher in their social interactions where each is making a contribution in the construction of the new or desired knowledge.

In the social interaction between the students and the teacher, the zone of proximal development (ZPD) has a function of assessing the students' learning processes as well as evaluating the instructional practices of the teacher or the mediator. Daniels (2005) restudied Vygotsky's theory of cognitive development and believed that ZPD is

operating at three levels. The first level is associated with the concept of scaffolding, a term that was introduced by Vygotsky and was later popularized by Bruner, which refers to the difference between the student's initial independent performance and his or her performance at the final stage after assistance by the teacher (Bruner, 1968). Guerrero and Villamil (2000) referred to the concept of scaffolding as the process by which tutors, parents, teachers or more expert peer help someone less skilled solve a problem. According to Bruner (1978), the concept of scaffolding is characterized by five important features: (1) reducing the complexity of the task, (2) getting the student's attention and keeping him/her focussed, (3) offering models, (4) extending the scope of the immediate situation, and (5) providing support so that the student moves forward in his or her learning and does not lose focus.

The second level is cultural ZPD which is related to the development of concepts. Vygotsky was trying to distinguish between scientific concepts and everyday concepts because he believed that scientific concepts are highly organized and very academic while everyday concepts are seen to be closely connected with the particular contexts and lacking in other aspects of the system (Sutherland, 1992). In school settings, scientific concepts are learned as part of the cultural knowledge system with clear verbal definitions which lead to learning. In other words, scientific concepts are those that arise from formal teaching in the classroom. On the other hand, everyday concepts are those that arise from a child's own observations, generally at home in the course of everyday life or at least outside school, where they are not made conscious, and sometimes are used with ease and without awareness of the concepts. According to Sutherland (1992) and Daniels (2005), in order for the child to achieve mature concepts, the child brings to the classroom the richness of everyday concepts which merge with the logical scientific concepts through teacher guidance. In this case, the teacher then sets up the adult pattern of thinking and those mature concepts that the child aspired to learn. The third level of ZPD deals with the social ZPD which is very similar to the second level but the emphasis is on the difference between cultural knowledge provided by social, historical contexts and everyday experiences, that is, the difference between understanding knowledge and active knowledge.

Role of Language

In Vygotsky's theory, thinking is considered as a form of inner speech which allows humans to reflect, plan and regulate their own actions (Vygotsky, 1986). Vygotsky recommends that by talking to others a child develops awareness of the communicative function of language which is one of the most crucial aspect of cognitive development. He emphasised the role of language as a mediational tool, that is, using the language to learn, in the process of the child's learning (Ellis & Barkhuizen, 2005; Sutherland, 1992). Ellis and Barkhuizen (2005) studied the role of language and pointed out that by learning through sharing and collaboration with others during social interactions, the child subsequently internalises the language for independent use. Vygotsky described this as a shift from other-regulation during the social interaction to independent self-regulation (Sutherland, 1992; Vygotsky, 1978) where the child is able to take the regulatory role of his or her own learning.

2.3 Historical background of cognitive acceleration

In describing his four stages of development, Piaget pointed out that children's levels of understanding slowly develop in order to move to the next stage. Piaget's own view was that "such development took time and could not be hastened" (Duckworth, 1996, p. 32). During the Woods Holes conference in 1960 in Massachusetts, American educators questioned him: "If it is true that children's level of understanding develops so slowly, what can we do to speed them up? Or can you suggest ways in which the child could be moved along faster through the various stages of intellectual development in mathematics and sciences?" (Duckworth, 1996, p. 34). After the Wood Holes conference, Piaget's explanation was understood by most American educators, physicists, and psychologists that children's understanding and thinking ability could not be accelerated at all. But in fact, that was not what he meant to convey. According to Duckworth (1996), Piaget simply meant to question the reason for doing so, and for him "the question was not how fast we could help intelligence grow, but how far we can help intelligence grow" (p. 38). However, in later life Piaget acknowledged the possibility of cognitive acceleration with training but maintained that the order of development would remain the same.

Criticism of Piaget's ideas began with Vygotsky and continued with Bruner in the 1960s and 1970s. They too believed that understanding and cognition can be engineered and moulded by an outsider and that complex knowledge could be

decomposed into simpler parts where the children can understand it easily and faster. As Bruner (1968) stated “any idea or problem or body of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form” (p. 44). According to Bruner, the criticism of Piaget’s ideas played a role in stimulating another body of research that had great significance for education. Most educators followed learning research and sought ways to speed up the development of key ideas that, at their natural pace, develop slowly (Duckworth, 1996). Bruner recommended teachers to search for better teaching pedagogies that can persuade slower learners, stimulating lazy learners and engaging children from deprived backgrounds. He also urged teachers to help students so that their cognitive development can move through the successive stages as quickly as possible (Bruner, 1968; Sutherland, 1992). Sutherland (1992) stated “We don’t have to wait for a certain level to develop in a student, as Piaget had given us to understand. We don’t have to wait for the student to become ready. If we are sufficiently ingenious and enterprising in our teaching techniques, we can accelerate this readiness. We should reject Piaget’s determinism” (p. 67). These comments gave rise to a number of research studies that sought to determine if it is possible to accelerate children’s cognitive development.

Within learning research, many programs that were developed drew from the cognitive development theories of Piaget and Vygotsky. For example, Bruner’s theory is based on both Piaget’s and Vygotsky’s theories, emphasizing Piaget’s stages of development and from Vygotsky, he elaborated the crucial role of language. On the other hand, Ausubel (1968) recognized Piaget’s idea of constructivism because it is important in concept formation. From Vygotsky’s theory, Ausubel used the ideas of the development of scientific concepts to elaborate the role of teaching in concept assimilation which is achieved through meaningful reception learning. Ausubel emphasized the importance of modifying technical language of the subject and present only to the students what they can cope with. In regards to his cognitive development program, he argued that the teacher’s first priority is to help students to grasp the appropriate terminologies and language of the lesson (Sutherland, 1992). However, Ausubel was criticised by White (1988) and other learning theorists of 1960s as he assumed all students learned in the same way, regardless of the student’s social and physical context or environment (Sutherland, 1992).

The most comprehensive intervention program, however, is the one by Feuerstein and his colleagues in Israel, the Feuerstein's Instrumental Enrichment (FIE) program (Feuerstein, Rand, & Hoffman, 1980). The aim of the FIE was to change the intellectual processing ability, self-concept, and motivation of many Israeli adolescents who are regarded as having 'low mental ability' on measures of intelligence tests (Adey & Shayer, 1994). This intervention program influenced Adey and Shayer by highlighting how cognitive theories from different schools can be used in the design of a cognitive acceleration program.

2.4 Cognitive acceleration

Cognitive acceleration is a theoretical view that students' thinking and ability to learn can be improved through well-designed systematic training (Demetriou, Efklides, & Gustafsson, 1992). Adey (1988) described cognitive acceleration as an application of some special learning and teaching procedure(s) in students' classes which results in their attaining higher levels of cognitive development more quickly than if they had not been presented with these procedures. In another word, "it is a process of accelerating students' natural development process through different stages of thinking ability, towards the type of abstract, logical and multivariate thinking which Piaget describes as formal operations" (Adey, 1999. p. 5). In recent years, there has been a growing development of curriculum design programs aimed at accelerating cognitive development in primary and secondary schools (Adey & Shayer, 2002; Adhami & Shayer, 2007; Endler & Bond, 2008; Finau, Treagust, Won, & Chandrasegaran, 2016; Venville & Oliver, 2015). These programs have goals to provide assistance to the classroom learning by fostering the students' abilities to think effectively and thus improve their problem-solving skills as well as their academic achievement (Adey, Shayer, & Yates, 1989, 2001).

There are three main hypotheses connected with the development of cognitive acceleration. The first hypothesis is that the central cognitive mechanisms in the human brain contain some unique intelligence that best operates in various contexts (Baddeley, 1990; Duckworth, 1996). Based on this hypothesis, educators understand that students' cognitive function can be influenced by how teachers design their curriculum materials and the pedagogy utilised. Consequently, the curriculum materials should be designed based on the required thinking skills needed to be

achieved at a particular cognitive stage. Effective teaching pedagogies should challenge the cognitive ability of the students and allow them to actively engage in their discussion so they can all arrive at some reliable conclusion together.

The second hypothesis emphasises the idea that a child's cognitive ability develops with age. As noted earlier and according to Inhelder and Piaget (1958), children pass through a series of stages of intellectual development that are qualitatively different from each other, from the sensory-motor stage to the formal operational stage. Taking consideration of these stages and students' characteristic differences can provide guidance for teachers and educators in the design of appropriate curriculum materials that can help develop students' cognitive abilities.

The third hypothesis is related to Piaget's theory that cognitive development could be influenced by the environment. Piaget and Inhelder (1967) described cognitive development as a process of adjustment to the environment. According to Hong (2010) it is a "process of balancing and adaptation between how a child sees the world around him or her and the effects the world has on the child" (p. 16). When the children's experiences are coherent with their views, they will change their views to understand the environment around them better. The idea of these works is to create an environment that will help stimulate students' thinking ability. As Kim (2005) explained "the environment is important to the children's development because it can accelerate or decelerate development" (p. 9). In addition, teacher's teaching pedagogy and the curriculum play major roles in providing the right learning environment for students to achieve the desired knowledge.

2.4.1 Cognitive Acceleration in Science Education (CASE)

Adey, Shayer and Yates (1989, 2001) developed curriculum materials known as the Cognitive Acceleration in Science Education (CASE) program designed to accelerates students' cognitive development that was implemented in secondary schools in England. The CASE program has made a positive influence on students' science learning as well as examination performances in many high schools in England, suggesting that the CASE program can foster students' thinking skills and ability towards what Piaget termed 'formal operational thinking' (Adey, 1999).

The curriculum analysis in 1970s showed that the science curricula in the United Kingdom (and other countries in the world) contained many science concepts that had a conceptual demand beyond the current understanding and thinking ability of the students (Adey, 1999; Shayer & Adey, 1981). This problem led most science teachers to teach science using procedures and rote learning of definitions and concepts instead of trying to teach for conceptual understanding. When Shayer and his colleagues conducted a national survey in Britain to determine the levels of cognitive development of a large representative sample of student population, they found that only about 28% of 14 year-olds were able to think abstractly and logically at a level which Piaget described as 'formal operations' (Adey, 1999). At the same time, using the Curriculum Analysis Taxonomy, which is designed to assess the cognitive demand of the curriculum on learners, most secondary school curricula required formal operational thinking to be fully understood (Shayer & Adey, 1981). Thus it was clear that only a small proportion of students would be able to learn secondary school science effectively. Subsequently, the CASE project was reviewed and set up to investigate the possibility of increasing the proportion of students that would be able to use formal operational thinking by the age of 14 years (Adey, 1988). The revised CASE project combined the cognitive development theories of Piaget and Vygotsky and designed a new curriculum and teaching pedagogy with the aim to accelerate the thinking skills of the students in science.

From Piaget's cognitive development theory, the CASE program uses the mechanism of construction, especially the notions of cognitive conflict and accommodation to structure and design the lessons. Those lessons aim at providing students with skills, knowledge and experiences that will help them develop formal operational thinking. Also, the lessons are designed to bring about cognitive conflict which can be resolved by the construction of more powerful problem-solving strategies. Piaget argued that when a child responds to cognitive challenges his or her thinking ability develops and improves. In addition, if the child is puzzling with the new experiences which cannot be solved using existing schemata, this can stimulate the development of more powerful schemata. Piaget introduced the term schemata to describe how a child is putting his or her thoughts together and making sense of the world or of his or her environment. Similarly, Vygotsky's theory emphasises the teacher's role in the CASE classroom. Vygotsky argued that the teacher should extend and challenge the student

to go beyond his or her comfort zone. For example, the learning task that already is within the student's capability does not provide the type of challenge that can stimulate cognitive growth. In alignment with the concept of the zone of proximal development (ZPD), the teacher's duty is to try to achieve the full potential of development for each student in his or her class.

The CASE program consists of 30 lesson activities designed by the CASE team and is published in the book called '*Thinking Science*' (Adey, Shayer, & Yates, 2001). Each activity is intended to replace a regular science lesson, approximately once in every two weeks during school term, and each lesson approximately lasts for about 70 minutes. All activities have a science context and each activity focusses on a specific reasoning pattern or schemata (Section 2.5.2 illustrates more information about schemata). The goal of the CASE program through its well-designed lesson activities and rich pedagogy is to develop formal operational thinking in the students, regardless of their age, thinking capabilities, and learning backgrounds. Unlike other thinking skills programs, the findings of the original CASE program in England demonstrated the effects of both long-term and transfer, suggesting the possibility of a meaningful change to general intelligence of these students. In term of the long-term effects, the majority of the students who participated in this study achieved statistically significantly higher achievement in science, mathematics, and English than the students in control schools in the British General Certificate of Secondary Education (GCSE), a national examination taken by these students, after three years of the intervention.

Following the publication of the CASE findings in England (Adey & Shayer, 1993, 1994), interest in the CASE program developed rapidly inside and outside of England. The theory and practical approaches used in CASE were also adopted in other disciplines, including mathematics, technology, geography, as well as in programs for younger children in early childhood and middle primary years (Adey, Robertson, & Venville, 2002; Adhami & Shayer, 2007; Backwell & Hamaker, 2003; Shayer & Adhami, 2010). In a similar manner, the CASE program has also been successfully implemented in other countries in the world including the USA (Oregon) (Endler & Bond, 2008), China (Lin, Hu, Adey, & Shen, 2003), Malawi (Mbanjo, 2003), Finland

(Hautamäki, Kuusela, & Wikstrom, 2002), Pakistan (Iqbal & Shayer, 2000), and Australia (Oliver, Venville, & Adey, 2012; Venville & Oliver, 2015).

2.4.2 **Cognitive Acceleration in Mathematics Education (CAME)**

The CAME program was a project funded by King's College, University of London. The aim of the CAME intervention program was to contribute to the teaching of mathematics in the lower secondary school where students have an opportunity for faster development toward formal operational thinking. The program was launched in 1993 in England with the intention to improve and develop the cognitive development of mathematics students in Years 7 and 8 at the early secondary school level (Shayer & Adhami, 2007).

The CAME project built on the CASE (Cognitive Acceleration in Science Education) project which claimed to have had a positive impact on students' cognitive development in science and other subjects such as mathematics and English. Similar to the CASE program, the CAME program developed techniques for teaching mathematics designed to promote cognitive development, with special lessons intended to bring cognitive conflict into the zone of proximal development (ZPD) of the child. The CAME program also attended to various learning aspects such as students' learning strategies, their conceptions or misconceptions, and their problem-solving skills. Hence, the key elements in the CAME approach were adapted from constructivism and the development psychology theories of Vygotsky and Piaget (Adhami & Shayer, 2007; Shayer & Adhami, 2007). The theories of Piaget and Vygotsky are put together in the CAME program despite some differences in their perspectives, notably epistemological questions about the nature and status of knowledge. Whereas "Piaget stresses individual cognition and sees logic and reasoning as the pinnacle of human thought, Vygotsky's sociocultural perspective prioritises language and social process, with community growth and verification of knowledge" (Goulding, 2002. p. 105). Moreover, Piaget's stage theory seems to imply that learning is a process of maturation as well as identification of higher order thinking whereas Vygotsky has a strong emphasis on the role of instruction and also acknowledges the social world of the classroom and possibility of accelerating learning through student's interaction with their peers or an expert adult.

The CAME program contained specially designed lessons that became the CAME curriculum. These lessons were designed by the CAME team and published in the book '*Thinking Maths*' (Adhami & Shayer, 2007). Similar to the CASE program, one CAME lesson replaced one regular mathematics lesson every fortnight over the intervention period.

The CAME lesson's activities allow students to develop certain skills in a learning environment where the correct answer is indeed not the main focus but the reasoning and thinking processes involved in trying to find the correct answer are considered to be the most important part. These lessons encourage students to share their experiences, discuss what they know and develop dialogue skills among peers as well as with the teacher. The activities are designed in such a way that they create opportunities for students to realize their limitations on the one hand and to make use of their own skills and reasoning to turn conflicting situations into meaningful investigations on the other. Isoda and Katagiri (2012) suggested that using these designed lessons in the classroom could nurture children's learning not only by developing their thinking ability and problem-solving skills but also by helping the child to learn mathematics by and for themselves.

Recent research has established that students who studied under this CAME program in England, either at the secondary school or primary school levels, tended to show large improvements on their achievement. Evidence from studies conducted by Shayer and Adhami (2007, 2010) illustrate the effects of the CAME program on students' cognitive development, as well as their social and academic achievements. According to Shayer and Adhami (2007), the findings have demonstrated the potential for raising students' achievement in mathematics, with evidence of long-term, far-transfer effects and high validity and reliability measures. After three years of the CAME intervention in Year 7 and Year 8, students in the CAME schools achieved higher results than their peers in the control schools in the British General Certificate of Secondary Education (GCSE), an examination taken when they were 16 years of age (Shayer & Adhami, 2007). In addition, Shayer and Adhami (2010) found in their two year study that students in the experimental schools had higher achievement scores than those students in the control schools in both mathematics and English.

Once the first CAME intervention program in England was completed with successful results, this theoretical and practical approach was successfully adapted and tried out in other places in the world including Hong Kong (Mok & Johnson, 2000), Ireland (Kerridge, 2010), Nigeria (Olaoye, 2012), Finland (Aunio, Hautamäki, & Van Luit, 2005), and Singapore (Hong, 2010). The findings of these CAME programs showed similar results with students having positive effects in their achievements in mathematics in Years 7 and 8 and these positive effects were also evident in the national examinations at the age of 16. In fact, some of these studies had modified the original CAME program to suit their problem contexts and students' current abilities.

2.5 The Theoretical Base and Pedagogy of CAME program

Knowledge exchange in education and conducting research studies play a major role in modern society. Higher levels of reasoning and thinking skills are needed by citizens in modern society to cope with increasing demands. This requirement has posed new challenges for current educational systems because educational goals pursued some decades ago need to be changed to accommodate both new and future ways of improving the schooling process of future generations. Torff (2003) and Barak and Dori (2009) agreed that one of these new educational aims is the development of thinking skills that allow students to find, manage, select, criticize and update their information. For this reason, teachers and educators should reform their teaching practices from a focus on a subject's content to fostering the cognitive skills that encourage students to be more active learners. For example, in most mathematics classrooms in Tonga, the students and teachers mainly practice the procedural or algorithmic skills in problem-solving as well as teaching and learning the mathematics problems. In many cases, when students scored well in class assessments or examinations (even if student have not fully understood what they have learned or practiced) by rote learning or memorising, the teacher assumes that student had learned enough mathematics knowledge and skills (Ministry of Education and Training, 2014). According to Barak and Dori (2009), this type of teaching and learning needs to be reformed and the development of cognitive skills encouraged. For the students' cognitive skills to develop, the teacher needs to build a new classroom culture where enquiry, collaborative learning and sharing of ideas become the important elements in their learning environment. In that case, school mathematics is no longer seen as an

individual activity, where the students expect to be trained in the application of rules and procedures but rather they should develop the mathematical conceptual understanding and thinking skills of the students through collaborative discussion and sharing of ideas with peers or the teacher. Several programs have the aim to improve students' cognitive skills including the Cognitive Acceleration in Mathematics Education program which is the focus of the current study.

The Cognitive Acceleration in Mathematics Education (CAME) program is based on the hypothesis that each child has some general cognitive functions, which develop with age and are influenced by his or her environment (Adhami & Shayer, 2007). This hypothesis is rooted in Piaget's and Vygotsky's theory of development where Piaget emphasized cognitive conflict as encouraging equilibration and the construction of reasoning patterns or schemata of formal operations (see Section 2.5 for more details). On the other hand, Vygotskian socio-cultural psychology theory emphasises the social construction of reasoning through metacognition and use of language (see Section 2.2.2 and Section 2.5.1 for more details).

Based on the ideas of these two theorists, Shayer and Adhami (2007) conceptualized the CAME theoretical framework as comprising five pillars (concrete preparation, cognitive conflict, construction, metacognition, and bridging), and schemata (the reasoning patterns). In combination, the five pillars and schemata are reviewed as the theory base to which CAME teaching approaches and characteristics of the lessons in the curriculum are deeply related (see Figure 2.1).

	Piaget	Vygotsky
Schemata of Formal Operations	✓	
Concrete Preparation	✓	✓
Cognitive Conflict	✓	
Construction	✓	✓
Meta-cognition		✓
Bridging		✓

Figure 2.1 Theory base of the CAME program

2.5.1 **The five pillars (principles)**

There are five central pillars that underpin the pedagogical methods of the CAME program, namely, concrete preparation, cognitive conflict, construction, metacognition, and bridging.

Concrete Preparation

Concrete preparation refers to the situation where the teacher portrays the nature of the problem in terms of descriptive concrete models. Thus, “concrete preparation involves establishing that the students are familiar with the technical vocabulary, apparatus, and framework in which the problem situation is set” (Adey & Shayer, 2002, 1993, p. 5). The aim of this principle is to enable students to become familiar with the terminologies and vocabularies to be used and the practical contexts of the tasks in the lesson. The terminologies are introduced and practiced in a set of circumstances requiring no more than concrete operational thinking. For example, in getting students to do word problem activities, the teacher should go through the vocabularies, resources, and language constructs so that the students fully understand what the problems mean. This is usually done initially in whole group discussions to enable the development of shared language between the teacher and student and is followed by small group discussions to give further practice.

Cognitive Conflict

Cognitive conflict refers to the situation when students observe an event which does not align with their previous experienced or view of reality (Adey & Shayer, 1993), the assumption is that students are compelled to reconsider the event (and possibly change their conceptual framework) and engage their minds in making sense of the new experience (Adey & Shayer, 1993; Maume & Matthews, 2000). In some cases, students are required to think and talk about the abstract idea or model to explain the given phenomena. Piaget described this term as the result of interrelationship between assimilation and accommodation of new knowledge or experiences within the cognitive structure of the student. If the input knowledge does not fit, there is a disturbance of the mental balance. According to Piaget, this balance can only be restored by the process of equilibration, that is, as a consequence of the interplay between assimilation and accommodation (Duit & Treagust, 1998). The process of

equilibration occurs during this interaction until the student is operating at full potential and has the ability to organize and regulate.

According to Vygotsky's social construction theory, this CAME principle requires the student to work within their zone of proximal development or what Newman, Griffin, and Cole (1989) called 'the construction zone.' This is the intellectual zone where students are struggling with their thinking and they need a well-structured and scaffolded support from the teacher or an expert. The teacher (or an expert) has to mediate the cognitive conflict by, for example, breaking the problem into small and manageable bits for the students. Also by doing this, the teacher can help students to place their focus on relevant aspects of the problem as well as the skills or knowledge that they are required to gain from it. Simply, such "cognitive conflict is considered the driver of cognitive growth because a mental struggle is required by the students to move beyond their current ways of thinking" (Oliver & Venville, 2017, p. 52). The CAME lesson activities and the teaching approach are designed to maximize the opportunities for cognitive conflict. However, in many cases the principle of construction where sharing of ideas with a collaborative effort between students and teacher or student and their peers is seen as a good method for students in solving the cognitive conflict.

Construction

The principle of construction is based on Vygotsky's notion of Zone of Proximal Development (ZPD) (Vygotsky, 1986); the construction of knowledge and understanding is a social process. Vygotsky claimed that human understanding first appears in a social context before being internalized by the individual. In other words, as children grow up observing and reacting to their surrounding environment, they tend to experience new knowledge and try adapting to it and so learn from each other (Vygotsky, 1978). Indeed, the children first experienced the cognitive conflict through adjusting their cognitive structures to cope with the new receiving experience. Then through sharing those experience with other, the children constructing new knowledge.

In the classroom it is a similar manner, once the students have experienced cognitive conflict, the teacher assists the students in resolving the conflict by giving them tools for constructing their understanding. This principle can occur both in whole class or

small group discussions but it is predominantly with small groups of students. To avoid chaos in the social interaction process and discussion, students need to be trained and motivated to respond to others' ideas and make conversation and dialogue more meaningful. For example, during whole class or group discussion the teacher should ensure that students take turns and listen to each other's ideas and prepare for feedback or comments. Also, the teacher can record students' ideas on the white board during the lesson as a basis for further thought and discussion from the rest of the class. In the group arrangement, sometimes the teacher already has a pairing or grouping strategy; however, the teacher should seek the best way of grouping the students so that students can feel comfortable to speak or share his or her ideas regarding their task.

A good cognitive acceleration program contains lessons which involve on-task constructive discussion in small groups as well as between groups. During group discussion, students learn how to express their ideas, how to state their position, how to be tentative, how to listen, how to challenge politely, and how to take risks. In this CAME program intervention, construction involves oral discussion around ideas, exploring them through group discussions, seeking explanations and making justifications. The whole class discussion periods are used for all group members to listen and share their group's idea with the rest of the groups, and for individuals to make corrections and refine their own understanding as they listen to other groups' sharing.

Metacognition

Metacognition which refers to cognitive processing of knowledge in the mind of the student involves a conscious reflection of how to control the thinking process as well as monitor that process. This principle has its origin in the work of Vygotsky (1986) – verbal thought - where the students process their thinking out loud. Often when students are faced with a difficult problem they resort to directing themselves out loud or talking it out with others so that they are in a better position to evaluate the soundness of their thinking. Adey and Shayer (1994) described metacognition as “thinking about one's own thinking, becoming conscious of one's own reasoning” (p. 67). Students are encouraged to think about their own thinking and reflect upon how

their thinking is changing as they solve problems. This process allows students to recognize that what they learned from the lesson activities is different from what they understood and could do prior to the lesson. This means that students can think back about the steps they took during their problem-solving activity and become aware of how their own conceptualisation changed during the activity (Perkins & Saloman, 1989).

Piaget considered metacognition as a form of conscious self-regulation of cognitive function which he defined as the keystone of formal operational thinking. According to Piagetian theory, metacognition is described in terms of construction, testing of theories in action, meta-procedural reorganization, and conscious reflection. However, conscious reflection only occurs when a student is capable of considering his or her actions and describing them to others. Zimmerman and Schunk (2001) and Pintrich (2000) shared a similar thought about metacognition in relation to self-regulation. These authors argued that metacognition involve the uses of self-regulatory processes such as planning, monitoring the learning, and reflection. Pintrich (2000) argued that self-regulated learning is a component of metacognition and that this component is a constructive process where students set their learning goals and “then attempt to monitor, regulate and control their cognition, motivation and behaviour, guided and constrained by the goals and features in their learning environment” (Wagaba, Treagust, Chandrasegaran, & Won, 2016, p. 254). Vygotsky provides a method for fostering metacognition through adult modelling and scaffolding. He asserts that a great deal of learning occurs in the presence of and is fostered by the activity of others. Generally, the expert acts as a supervisor or facilitator and gradually transfers supervisory control to the student. This will assist the student in gradually adopting the structure and regulatory activities as his or her own.

In defining metacognition as ‘thinking about thinking’, Frith (2012) commented on classroom dialogue during problem-solving activities where teachers try to bring out the best in students’ problem-solving strategies and understanding and allow them to reflect on their errors as well as alter existing or develop new thinking patterns. By examining teacher-student dialogue during problem-solving activities, teachers learned to be aware of not only knowing what and when to monitor but also how to monitor and evaluate the students’ thinking strategies (Hong, 2010; Perkins &

Saloman, 1989). For example, when teaching a geometry topic in a mixed-ability classroom, the teacher should focus on specific learning concepts and skills in order for the students to comprehend the concepts and representations. Regarding students who are struggling to understand mathematics concepts and skills, the teacher should guide them with some simple leading questions which can help students make a drawing of the abstract geometry concepts in their minds. Although researchers have some different views in regards to the concept of metacognition and how it works in education and in relation to the theory of cognition, they all conceptualise metacognition as consisting of two main components, namely, knowledge of cognition and regulation of cognition (Wagaba et. al, 2016; Zimmerman & Schunk, 2001).

Bridging

This is the final pillar of developing, abstracting, and generalizing reasoning. The teacher links the learning concepts that students learned in the CAME lesson activity to other contexts within the mathematics curriculum or in everyday life activities. Also, students are required to make explicit the strategies that they have developed and imagine how they can learn more about abstract thinking and reasoning on other levels or contexts. In some cases, this is an opportunity where the students prove for themselves whether they clearly understand the main concepts that need to be learned and if they can apply those learning concepts across contexts. Some studies revealed that utilising these five pillars on teacher's teaching pedagogy help enhance students' learning and problem-solving skills (Oliver & Venville, 2017; Shayer & Adhami, 2007).

Consequently, the relationship of the five principles to one another is important to consider in terms of the teacher's teaching pedagogy. Figure 2.2 illustrates the relationships and show how one principle relies on other principles. Moreover, the relationship between cognitive conflict and construction is in a spiral arrow, instead of a straightforward arrow. According to Adey (1999), when students are presented with a problem task with any sort of difficulty in thinking to which they cannot readily produce a solution, the students usually seek simple solutions. In other words, the students rarely seek a full understanding of the problem situation. However, they tend to settle for the minimum solution that will meet the immediate demands of the problem in the question. This behaviour reveals that cognitive conflict by itself does

not automatically lead to reconstruction of new concepts or reach a full understanding of the concepts. However, cognitive conflict must be maintained during the students' learning process and this can be done by the teacher through close questioning or through students' interactions with their peers.

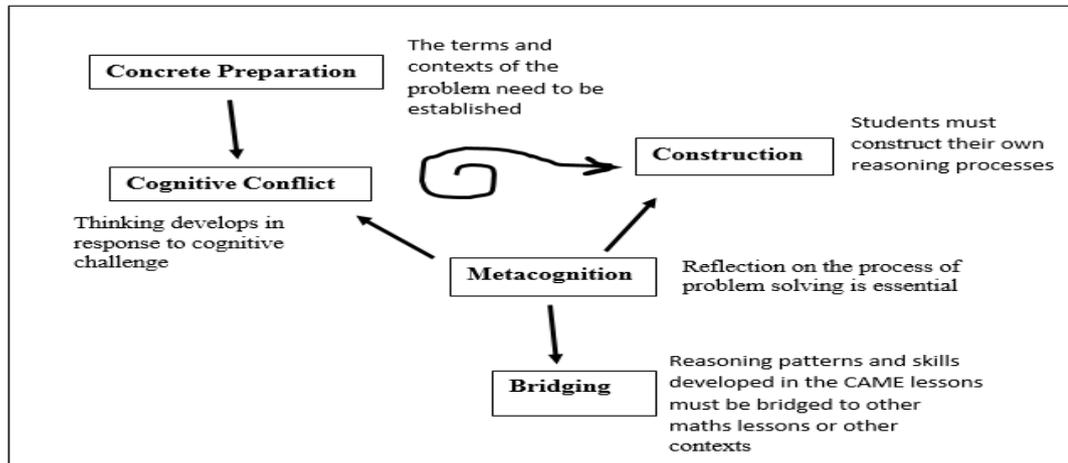


Figure 2.2 The five principles of the CAME and how they are related to one another (from Adey, 1999).

2.5.2 Reasoning patterns (or schemas)

Reasoning patterns or schemas refer to the child's conception of any object (Duckworth, 1996). For infants, schemas are how they know what to do and for older children or adults schemas are "the thoughts in their minds, their ways of putting things together and making sense of the world" (Duckworth, 1996, p. 26). Piaget described schemata (or schemas) as a collection of series of schema, and this concept is closely linked to the theory of learning. During the process of cognitive conflict, that is, when assimilation takes over accommodation or vice versa, this always leads to equilibrium for that schema at that particular stage. However, if a "new experience arises and upsets the equilibrium, the schema must adjust all over again" (Sutherland, 1992, p. 27). This process continues until the schema find their full efficiency and are better adjusted to the student's environment (Duckworth, 1996). In mathematics, Chi, Feltovich, and Glaser (1981) argued that desired knowledge and skills in mathematics can be accessible if the knowledge is adequately organised by suitable cognitive structures or the required schemas.

The CAME program consists of a set of lessons activities called *Thinking Maths* (Adhami & Shayer, 2007) which incorporate the five pillars and are based on the schemata of formal operations. Inhelder and Piaget (1958) characterized the schemata of formal operations that include control and exclusion of variables; classification; ratio and proportionality; probability and correlation; compensation and equilibrium; and use of abstract models to explain or predict. These schemas help capture both the pattern of relationships as well as their linkages to formal operations.

Control and exclusion of variables

When working on a mathematics problem-solving activity, students' understanding of the relationship between each variable in the mathematical activity (problem-solving activity) is important. So the main aspects of control and exclusion of variables strategy involve the identification of the relevant (or irrelevant) variables. In fact, most students at the concrete operational level of cognitive development have difficulties in identifying which variable is independent and which is dependent. For example, when doing investigations that required applying a mathematics formula or equation in the calculation, students tended to change more than one variable, say two variables, and attribute the effect to both. However, students at the formal operational stage see the need to change one variable at a time, while keeping all other variables the same. In some cases, students at the concrete level can only handle mathematical problems involving two unknown variables but at the formal level students can work on problems that have more than two variables.

Classification

Most students at the concrete operational level can classify and group things according to some given criteria. Also, usually these students cannot recognise that the way they conducted their classification is only one of many possible ways in which classification might be carried out. On the other hand, students at the formal operational level realise that classification operations are abstractions that involve inclusion and exclusion and may be part of a hierarchical system. These types of students first analyse the nature of the classification process and the selection criteria before they select the elements and place them into various categories.

Ratio and proportionality (or inverse proportionality)

A ratio can be described as a constant when multiplied with a given variable gives value to the other variable. For example, the straight-line graph equation $y = mx$ where x and y are two variables and m is the given constant or often called the ratio. Which mean, if y increase so as to x (but not in the same increase value as y) in order to maintain the balance of the two sides as m is constant. Although the students at the concrete operational level can work out arithmetical problems in some algorithmic manner, they may fail to use ratio in practical situations where it is applicable. On the other hand, proportionality involves the comparison of two ratios, for example, 3:5. In some cases, comparing two different quantities using proportionality thinking usually requires mental manipulation of at least four independent variables; to be able to make this comparison students need to have achieved formal operational thinking.

Probability and correlation

Probability is about understanding the causality and chance that something will happen. In learning mathematics, students at the formal operation level can appreciate the impossibility of controlling natural variations in social data and recognise the need for proper sampling (Mbano, 2003). Moreover, students should understand that sampling a population must ensure that all possible variations are highly likely to be represented and that averages can be used as reasonable measures for looking for differences not due to chance alone (Adey et al., 2001, p. 8).

Correlation, however, is used to describe the relationship between the input variables and the outcomes of the process. For example, in medical science, looking for an effect of a single treatment of a disease, the concrete operational level students usually look for the correlation of the cases of patients were treated and show some effects and patients that were not treated and appeared to have no effect. However, students at the formal operational level have the thinking ability to investigate the correlation of the confirming and disconfirming cases. For example, patients who were treated show some effects, patients who were not treated appeared to have no effects, patients who were not treated do show some effects, and patients who were treated showed no effects.

Compensation and Equilibrium

Compensation is a type of ratio, but it is an inverse of the proportionality ratio as described in the simple distant equation $s = vt$, when v (velocity) increases, t (time) decreases to keep the s (distant) constant. Children at the concrete operational stage can describe the qualitative relationship of compensation but are unable to determine the mathematical form. However, students who achieved the formal operational level are able to use and explain the mathematical form.

Equilibrium is complicated because it connects two compensation such as $ab = cd$ where the students will deal with at least four variables. With the students at the concrete operational level, they can do mathematical substitution of the three variables to find the fourth variable, however, if they want to use that same equilibrium ideas in any non-routine case, they need formal operational thinking. In addition, students at this formal operational stage can provide a possible explanation for the compensation relationship.

Abstract models to explain and predict

In mathematics, most of the formula and equations that use in problem-solving activities are abstract thinking. However, the teachers usually designed a model to help shape the images of the abstract ideas so that students can connect their thinking and understanding with required concepts that need to be learned. Students at the concrete operational level can only handle descriptive models, for example in the equation $y = mx$ these students can only say that if x increases so as y or if x is double so as to y variable. Usually concrete operational students can only do things in mathematics by following some sort of descriptive pattern. However, they cannot explain the reason behind why they do it that way. On the other hand, formal operational level students can produce explanatory abstract models which allow the students to explain and predict a given phenomena which in some way represents reality (Adey et al., 2001).

These reasoning patterns (schemata) are deeply addressed through the designed CAME lessons activities (see Table 3.4 in Section 3.3 of Chapter 3 for the details), and they provide the subject matter of the activities (Adhami & Shayer, 2007). However, in order for the teacher to cognitive challenge students at the right cognitive level, the teacher requires some understanding and experience on the nature of these schemata,

their characteristics and how they become elaborated over the years of their students' development.

2.5.3 **Characteristics of the CAME materials**

The CAME program uses specially designed lesson activities/materials and teaching approach to help students improve their thinking abilities by constructing their own knowledge and also empower the teaching pedagogy of the teachers. In fact, CAME program recognises a range of level of students' thinking ability in any classroom and any context. As a result, the lesson materials were designed to allow students to proceed in their own direction within their own capabilities with the teacher present as a facilitator and mediator. In addition, the CAME lessons are designed to bring about cognitive conflict which can be resolved by construction of more powerful problem-solving strategies. The CAME program approach behind the '*Thinking Maths*' (Adhami & Shayer, 2007) is a set of well-designed lesson activities that aim "to provide cognitive stimulation using challenging classroom tasks with an emphasis on big ideas or organizing conceptual strands in mathematics" (p. 5). These number of lesson activities that the students explore to answer a higher level of thinking questions. The activities may include diagrams, tables, graphs, figures, mathematical symbols, and text equations related to each mathematics conceptual strand. Section 3.3.1 of Chapter 3 has more details regarding these lesson activities.

The structure of each CAME lesson is based on an analysis of the level of difficulty of the concepts, starting from an easy task (concrete operations) leading up to more abstract task (formal operations). The underlying principles of these activities encourage collaborative learning which allows each student to contribute to the learning task and the group discussion, no matter what level of thinking ability they have. The idea is to allow each student to share his or her knowledge and experiences regarding the task and then draw from that source of knowledge in developing their thinking ability toward the formal operational stage (Adhami & Shayer, 2007). According to Olaoye (2012) and Kerridge (2010), the structures of the CAME activities lead students to higher levels of thinking, particularly with regard to concept development and the application of knowledge to new knowledge.

The cognitive agenda of the CAME program requires teaching that combines elements of investigation and instruction. In the mathematics classroom, teaching and instruction focus on a given objective and assume the ability of the whole class to benefit. However, the CAME program's focus is on students' thinking, and "how to orchestrate students' talk in the classroom flexibly in a trajectory towards higher order thinking" (Adhami & Shayer, 2007, p. 18). The teaching approach is divided into three Phases; whole class concrete preparation, small group collaborative learning, and whole-class collaborative learning (see Section 3.3 of Chapter 3 for more details). These three teaching phases emphasize the five pillars that emerged from the theories of Piaget and Vygotsky. Sometimes the five pillars of cognitive acceleration are discernible as being discrete and sequential within a particular lesson, although frequently they are highly integrated.

In the extent of lesson activities and teaching approach, the CAME program offers scope for the teacher to build up a new culture where inquiry, collaborative learning, and sharing of ideas become dominant themes. These teaching approaches could change the predominant view that school mathematics is no longer seen as an individual activity where students expects are trained in the application of formal rules and procedures (Adhami & Shayer, 2007).

2.6 Motivation and Self-regulation about Academic Achievement

Even though cognitive and mathematics achievement aspects are important, motivation and self-regulation also play an important role in students' learning. Zimmerman and Schunk (2001) posited that motivation and self-regulation are considered among the factors that affect the success and academic performance of students in science and mathematics. It has been identified that these two factors play an important role in influencing students' engagement in the learning process. Shayer and Adhami (2007) and Olaoye (2012) reported that students need to be motivated in order to benefit from the CAME intervention. In addition, these authors claimed that it is possible that the CAME program with its lesson activities and pedagogy can induce self-motivation and regulation in students' learning. With that reason, this research study was designed to enable this claim to be investigated.

Many studies on motivational beliefs have suggested that there is a positive relationship between self-regulation, motivation, and academic achievement. These studies have shown that motivation and self-regulation influence students' learning engagement and academic achievement (Mega, Ronconi, & De Beni, 2014; Velayutham et al., 2011; Wolters, 1999). In this section, motivation and self-regulation are further discussed.

2.6.1 **Motivation**

What type of motivation is involved in learning? Why do children learn? According to some behaviourists, students will only learn if they are rewarded extrinsically for performing the tasks. On the other hand, Piagetians claimed that students do not need extrinsic rewards from the teacher. If the students find learning intrinsically exciting, they will learn anyway (Mega et al., 2014; Pekrun, 1992; Sutherland, 1992). Although these two schools of learning have a disagreement in the type of motivation involved in learning, their concerns indicate the critical nature of motivation as a factor that causes learning to occur.

Previous studies in the area of motivational learning revealed that motivation is an essential effective factor in students' learning. It plays a crucial role in students' conceptual change processes, critical thinking, learning strategies and academic achievements (Pintrich, Marx, & Boyle, 1993; Velayutham et al., 2011; Wolters, 1999). Pekrun (1992) argued that lack of proper consideration of students motivational beliefs such as self-efficacy, goal setting, and task value when engaged in academic tasks, will profoundly impact upon their cognitive strategies of learning and hence their academic achievement. For example, when a student is working on a mathematical task over which he or she feels bored and is not interested, that boredom feeling will nevertheless lead to reduction of the students' motivational beliefs and to a cognitive escape from completion the task, resulting in poor mathematics achievement.

In conducting a study that focussed on students' learning strategies, Leutwyler (2009) found that motivational beliefs helped students facilitate their learning, sustain effort and attention and enable completion of the given tasks which usually lead them to better learning achievement. For example, with the trial experimental CASE

intervention findings, Adey and Shayer (1993) were criticized for failing to provide a clear explanation of why some students learned and achieved better, whereas others did not. According to Leo and Galloway (1996), student's motivational beliefs might provide the missing explanation for this given question. Leo and Galloway defined motivational beliefs as an individual variable and it refers to a type of behaviours such as self-efficacy, goal orientation, and task value that students bring to academic situations and problem-solving activity. They claimed that the question of students' reason for learning sciences, and what motivated them to learn sciences had not been considered in the CASE program.

In this section, the focus is on some motivational constructs that have been known to be closely associated with the concept of self-regulated learning and appear to play a crucial role in students' learning commitment and achievement. In particular, three aspects of motivation are theoretically and practically linked: learning goal orientation, task value, and self-efficacy (Bandura, 1997; Eccles & Wigfield, 1995). Bandura (1997) and Eccles and Wigfield (1995) claimed that these three aspects had been identified as significant predictors of student motivation. In addition, Zimmerman (2002) posited that these motivational aspects happened to influence various self-regulatory strategies on students' learning processes, and contribute in promote and sustain of academic achievement. These three aspects of motivation are discussed below.

Learning Goal Orientation

Goal Orientation is considered as an important dimension in the field of motivation which stimulates goal-oriented behaviour within the student's learning and also provides a theoretical perspective to help explain the reasons for students' engagement in a task (Kaplan & Maehr, 2007; Pintrich, 2000). According to Kaplan and Maehr (2007), goal orientation originally known as 'situated orientations', focussed on achievement tasks or the content of what students are attempting to achieve on the task. However, the definition was revised and instead of focussing only on the purpose for action (or what to achieve), goal orientation defined and including the why and how students are trying to achieve the desired objectives of the task. There are two major goal orientations that known to frequently investigated in the educational context, namely, learning goal orientation or sometime called mastery goal orientation

(which focusses on learning, understanding, and mastery tasks) and performance goal orientation (which concerned with demonstrating competence and focuses on comparative standards relative to others) (Ames, 1992; Dweck & Leggett, 1988; Kaplan & Maehr, 2007). Previous research studies had revealed that performance goal orientation is unrelated to a deep reasoning form of learning and that it appears to hinder student motivation and achievement (Midgley, Kaplan, & Middleton, 2001; Urdan & Schoenfelder, 2006). For these reasons, performance goal orientation was not included in the discussion to support this study.

Learning goals-oriented students focus on sustaining learning commitment, self-improvement, understanding, and in developing new skills (Kaplan & Maehr, 2007; Velayutham et al., 2011). Kaplan and Maehr (2007) have indicated that learning goals oriented students have a high possibility of achieving positive learning outcomes such as better academic achievement and problem-solving skills. Generally, learning goal orientation refers to students' personal development and growth that guides their achievement and task engagement behaviours. In addition, students who perceived learning goal orientation has been "regularly found to be associated with positive outcomes such as self-efficacy, persistence, preference for challenge, self-regulated learning, and positive affect and well-being" (Kaplan & Maehr, 2007, p.142). Dweck and Leggett (1988) and McLellan (2006), stated that learning goals oriented students are expected to work diligently and make real efforts to mastery the task's concepts. Moreover, those type of students "view mistakes as part of the learning process and will not be concerned with other students apparently doing better or understanding more quickly than themselves" (McLellan, 2006, p. 784). Chatzistamatiou, Dermitzaki, Efklides, and Leonadari (2015) reported that learning goal orientation has a significant influence on students' mathematics achievement as well as metacognition strategies such as planning, monitoring, and regulatory strategies when doing problem-solving.

Task Value

Task value has been highlighted by the expectancy-value theory as having a pivotal role in structuring students' motivation to learn (Lee, 2015; McLellan, 2006; Pintrich, 2000). Lee (2015) stated that task value is a motivational construct that leads student's decision to be more persistence with the task at hand. The amount of task engagement

that students may put into task-solving activity lies on how the students value the task to their individual needs and interests. Wolter and Rosenthal (2000) suggested that, theoretically, students who believed that the learning task is interesting, important, and useful were seen to put greater effort and more persistence in the process of completion the task. Similarly, Pintrich and Zusho (2002) along with Zimmerman (2000a) emphasized that students who value the task activity were able to applied variety of thinking strategies, such as cognition and metacognition which require more effort, more concentration and self-reflection in the task problem-solving. As students perceive this behaviour, their level of learning motivation increases. For example, if the student is given a task to solve and strongly believes in achieving the goal for the given task, that level of value the task will increase the effectiveness of the student effort, concentration, commitment, and the level of motivation in the process of trying to complete the task.

Eccles and Wigfield (1995) argued that task value is a compromise of three main types of value, namely, interest, importance and utility. According to Eccles and Wigfield, interest refers to the students' learning enjoyment when engaged in solving the task because usually the contents matter. Importance is defined by the degree to which students find the task useful and meets their needs, and utility refers to the students had value the task because it is instrumental in reaching variety of goals. In regard to utility, Pintrich and Schunk (1996) defined it as the "usefulness of the task for individuals in terms of their future goals, including career goals and is related more to the ends in the means-ends analysis of a task" (p.295). Lee (2015) postulated that these three types of values operate collectively in defining the quality of the task and "determine the achievement value a task might have for each individual student" (p. 63).

Previous research studies in the field of motivation have revealed that task value is a good predictor of both student motivation and student learning achievement (Ding, Sun & Chen, 2013; Eccles & Wigfield, 1995; Lee, 2015; Niculescuc & Cosma, 2013; Wolters, 2004; Zhang, Solmon & Gu, 2012). According to Wolters (2004), students who find the subject content to be interesting and useful are more likely to value the task; his research showed that students also used deeper reasoning strategies and more self-regulatory strategies in solving the tasks. Similarly, a study conducted in

mathematics suggested that students who valued and were interested in the mathematics subject matter showed a positive correlation between their mathematics achievement and the amount of effort they put into cognition and reasoning strategies (Berger & Karabenick, 2011). Consistent with this view, Ahmed, van der Werf, Kuyper, and Minnaert (2013) posited that changes in value and emotions such as interest and enjoyment were systemically associated with changes in self-regulatory and cognitive strategies as well as the students' achievement in mathematics. This study claimed that if students find the learning activity interesting and relevant to what they want to learn, they can cognitively engage in their learning and try to comprehend the task with the learning materials presented to them.

Self-efficacy

Self-efficacy is defined as the student's belief in his or her capabilities to design and implement plans in order to achieve the desired outcome (Bandura, 1997; Lee, 2015). According to social cognitive theory, students are more likely to learn the learning task if they are confident and believe in their capabilities that they can produce the desired outcome required for the learning task (Bandura, 1986, 1997). In other words, students with high self-efficacy are more likely to put effort, consistently evaluate their progress, and apply self-regulatory strategies. On the other hand, if students believe they are not able to produce the results, they will not try to complete the task. The degree of self-efficacy will affect what they choose to do, and the amount of effort that they will put into any undertaking, how long they will persevere, how much stress they experience, and how they cope with problems and obstacles. According to Zimmerman (2000b), in some context, self-efficacy is dependent on the difficulty level of the specific task such as solving a mathematical words problem with different levels of abstract algebraic expressions. In some case, if the task is familiar to the student and if his or her cognition easily specified the task's concepts, the self-efficacy within the student increased and can transfer across the task activities or contexts (Pajares & Kranzler, 1995). Thus, self-efficacy is regarded as a relevant predictor of students' choice of task, the amount of effort they can put into the task, and their persistence in facing difficulties when working on the task (Bandura, 1997; Multon, Brown, & Lent, 1991).

Bandura (1997) reviewed some studies on self-efficacy in various settings and claimed that self-efficacy has a significant role on students' learning behaviours. In comparison to the students who doubted their capabilities, he found that students' with high perceived self-efficacy can make changes in their reaction behaviours, such as levels of psychological stress reactions, changes in their self-regulatory behaviours and working effort. Furthermore, these students work harder, participate more often, persist longer, and can control their emotional reactions when they experience some unfamiliar difficulties in their learning.

Research by Zimmerman and Schunk (2012) has shown that students with perceived high self-efficacy who believe in their individual capabilities when performing the learning tasks tend to use more cognitive and metacognitive strategies for achieving the desired skills and knowledge addressed by the learning task. In addition, these types of students are more successful in school activities than those who doubt their competence and capabilities. Lee (2015) and Zimmerman (2000b) emphasized that students who feel uplifted with their academic performance tend to increase their level of learning efficacy and increase their learning depending on what they believe they are capable of and what they hope to achieve. However, with these results, it can be argued that self-efficacy is associated closely with self-regulated learning. According to Pintrich (2003), students who believe in their capabilities and competence in the task are more likely to be self-regulating. Self-regulation is discussed in the next section.

2.6.2 **Self-Regulation**

According to Garton (2004), "one of the main challenges for students is the ability to take responsibility for solving a problem" (p. 84). This view refers to students' capacity in developing self-regulated behavior and taking responsibilities for their learning process. According to Pintrich (2000), self-regulation is defined as a constructive process where students set up their learning goals and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by the goals and contextual features of the environment. Schunk and Ertmer (2000) refer to self-regulation as "self-generated thoughts, feeling, and actions that are planned and systematically adapted as needed to affect one's learning and motivation" (p. 631). McCann and Garcia (1999) defined self-regulated students as

students who are interested in the learning task because the task requirements match with their needs. Zimmerman (2000a, 2002) and Cleary and Chen (2009) defined self-regulation as an individual proactive process rather than as a reactive event. The individual adjusts his or her thoughts, feelings, and behaviours based on performance feedback and then regulates his or her learning in order to attain the desired goal. In this case, the feedback from a prior task performance helps the individual to adjust and make corrections on the learning strategies in order to optimize academic outcomes. Furthermore, Zimmerman (2000a) indicated that self-regulation is not an academic skill or mental ability. However, it is a self-directive process and self-belief behaviour that enables students to transform their mental abilities and individual skills into academic skills and knowledge. Hence, self-regulated students personally motivate themselves to engage in the learning process as well as direct their own effort on that learning process in seeking the new knowledge rather than relying on teachers, parents, or expert instruction. Boekaerts, Pintrich, and Zeidner (2000) and Cervon and Pervin (2010) also stated that students who perceived high level of self-regulation skills are more likely to be academically motivated and probably self-generated in striving to completing a learning task.

Moreover, Zimmerman (2008) reiterates that the core requirements of self-regulated learners are personal initiatives, perseverance, and adaptive skills. It is a controllable learning process where self-regulated students can evaluate the learning task, constantly plan, organise, and regulate their learning throughout the process (Mega, Ronconi, & De Beni, 2014). Self-regulated students usually set learning goals then monitor their effort and learning progress in striving to achieve those goals. At some stage in that process, students adapt and are able to regulate their cognition, motivation, and learning behaviours in order to reach the setting goals (Mega, Ronconi, & De Beni, 2014; Pintrich, 2004). Along their learning process, their goals or standards help them decide whether their learning strategies should continue in the same way or if some change is required. Although these theories and models describe self-regulation in various perspectives, they largely share the notion that self-regulated learners are constructive learners, and that they use a variety of cognitive and metacognitive strategies in constructing knowledge as well as to control their effort and behaviours throughout the learning process (Zimmerman, 2000a). In brief, the characteristics of these types of students are that they believe learning is a proactive process, they are

self-motivated, and they use strategies that enable them to achieve desired academic results and goals.

2.7 Summary

This chapter has reviewed some of the research related to the features of the CAME program including the cognitive development theories that underpin this study. The historical background of cognitive acceleration and its theoretical base and pedagogy framework was also presented. In addition, the review included some research in the area of learning motivation and self-regulation in mathematics and how these two aspects are related to students' cognitive and mathematical achievements. A substantial amount of mathematics and science education research has been conducted in the field of cognitive acceleration and student-centred learning pedagogies

Moreover, the revision of the related literature revealed that the CAME program holds a real potential as a vehicle for raising students' mathematics achievement because it is well founded on widely accepted theories of cognitive development and conceptual change. In addition, the literature also found that CAME has had some clear success in terms of quantitative gains in the contexts and places in which it has been implemented. For this reason, the CAME program was chosen in the present study as a vehicle for addressing the poor academic performance of Tonga students in mathematics in the secondary school levels.

Chapter 3 Research Methods

This chapter describes the research design and methods to enable the readers to understand how the data was collected and analysed. To investigate the benefit of implementing the CAME program in Tonga secondary schools, this study collected quantitative data on students' mathematics achievement, motivation, and self-regulation using three validated instruments, supplemented by students' interviews. This study also collected qualitative data on teachers' perceptions on their teaching of the CAME program through interviews. Both quantitative data from the instruments and qualitative data from the interviews were used to answer the research questions.

3.1 Research Design

In order to investigate the effectiveness of the CAME program, this study adopted a quasi-experimental design and collected both quantitative and qualitative data from students and their mathematics teachers. These data were analysed and used to compare students' achievement, motivation, and self-regulation between the experimental and comparison groups, where the experimental group students were taught with the CAME program and the comparison group students were taught with regular textbook-based activities. This study is, however, a quasi-experimental study with non-equivalent comparison groups (Cohen, Manion, & Morrison, 2011) because (1) the school and classroom settings already existed and it was impossible to randomly assign the participants into experimental and comparison groups (see Section 3.2 for more details); and (2) the researcher had no control of some independent variables within the participants such as socio-economic background, students' academic history, and teachers' teaching experience, which may impact upon the results. Although a quasi-experimental design does not achieve the internal validity of an experimental design, it offers an alternative means of investigating causality on the situations where randomization of the experimental and comparison groups is not possible. Cook and Campbell (1979) claimed that in such settings, a quasi-experimental design can successfully be used to determine causal relationship, explain the events and provide discussion of details how the event can be achieved.

Within a quasi-experimental design, both quantitative and qualitative data were collected to give information on the impact of the CAME intervention and to answer the research questions. The combination of these two data sets boosts the capacity and strengths that exist between quantitative and qualitative research approaches and also enables the researcher to understand the phenomenon more fully than is possible using either approach alone (Burns, 2000; Creswell & Clark, 2008). In this study, quantitative data from a pre-test and post-test was used as the first approach of the data collection. Semi-structured interviews with selected participants were also conducted to gather elaborated responses on the quantitative data.

This quasi-experimental design with comparison and experimental schools was set up using the schedule shown in Table 3.1. Both experimental and comparison group students took the same pre-tests before the intervention. In the experimental group, the students got 16 CAME lessons in addition to the regular lessons, and the teachers got 3 Professional Development (PD) workshops to support their implementation of the CAME program (see Section 3.3). After eight months of intervention, both experimental and comparison group students took post-tests, which were followed by semi-structured interviews with selected students and teachers at the end of the intervention (see Section 3.4 for more details).

Table 3.1 The CAME program main study schedule

Time Frame (2014)	Experimental group	Comparison group
February, 2014	1 st PD	Pre-test (NRT1 & SALE)
March		
April		<div style="display: flex; justify-content: space-between;"> <div style="width: 45%; text-align: center;"> 16 CAME lessons + Regular lessons curriculum </div> <div style="width: 45%; text-align: center;"> Regular lessons curriculum only </div> </div>
May	2 nd PD	
June		
July		
August	3 rd PD	
September		
October		
November		
	Post-test (NRT2 & SALE) + Interviews	

3.2 Participants of the study

Over 330 Form 2 students (12 – 14 years old) and their Mathematics teachers from four schools in Tonga participated in this study. With the intention of facilitating the educational needs of the rural communities, this study chose four schools in the rural area of Tongatapu. Three of those four schools were treated as the experimental group and one school as the comparison group in order to match the number of students in each group (see Table 3.2 for more information). All four participating schools were church-affiliated, and the majority of students came from low socio-economic families in outlying rural villages and farming communities. As explained in Chapter 1, these students attended these church schools because they were not accepted in the government secondary schools due to their low achievement scores in the Year 6 Tonga Secondary School Entrance Examination (SSEE).

Table 3.2 Comparison of the four participating schools in 2014

	Experimental			Comparison
	School 1	School 2	School 3	School4
School location	rural	rural	rural	rural
SSEE minimum entrance scores	160	160	160	165
Student-teacher ratio	35:1	39:1	33:1	35:1
Number of Form 2 Mathematics teachers	2	2	3	4
Mathematics teachers' qualification	BA(1), Dip(1)	BSc(2)	BSc(2), Dip(1)	BSc(2), Dip(1)
Number of Form 2 Mathematics classes	4	4	5	7
No. enrolment in Form 2 Mathematics	70	80	97	161
No. of students participated in the study	51	75	93	119

All the participating schools were well equipped; each classroom had enough chairs and desks for each student to use. The schools had provided mathematics textbooks for each student to use in school and also outside school. In most mathematics classrooms, the number of students per class ranged from 25 to 30. Participant teachers had completed a Diploma in Education and some had a degree in mathematics; each

teacher had been teaching for over five years at the secondary school level. The majority of these teachers taught two different subjects (for example, mathematics and sciences) and some taught two different levels (for example, Forms 2 and 3).

The experimental group consisted of seven Mathematics teachers and their Form 2 (Year 8) students from three schools (219 students in total). These schools in the experimental group belonged to the same church, where they were operated and directed by the same education board of trustees, education system, and church leaders. The schools had the same minimum entrance score of SSEE to enrol in Form 1 (Year 7). Principals of these three schools explained that majority of the students were not performing well in mathematics.

The comparison group consisted of four Mathematics teachers and 119 Form 2 students from one school. This school was operated by and funded by the Catholic Church. However, students were of mixed religious beliefs with a large number of students from various churches (Catholic, Methodist, Anglican, and Tonga Church) in the country. Despite their religious beliefs, some students selected this school (the comparison school) because it is closed to where they lived. According to the principal of this school, mathematics was a subject in which students were performing poorly at every level.

3.3 Instructions and Support

3.3.1 CAME lessons

A current trend in mathematics teaching is the increased availability of planned lessons with relatively detailed guidance to teachers on their conduct of the lessons in their classrooms. In the Tongan classrooms, most of the planned lessons address idealised or generalised class of students and necessarily offer guidance on a restricted set of expected students' responses (Ministry of Education and Training, 2014). In addition, most experienced mathematics teachers would normally use their experience by applying a variety of responses that are not noted in the guidance given, correcting errors and providing answers, as long as the lesson is completed within the planned timeframe. This approach is difficult in the CAME lessons where the agenda is on the logical reasoning underlying the topic rather than the formal mathematics itself. The

lessons are characterised by group interactions and the emphasis is on individual or group formulations of solutions to problems rather than just on the end result. The outcome of the lessons is enabling the thinking processes and sharing of ideas rather than focussing on the specific knowledge or skills themselves.

The CAME intervention used in this study is similar to the CAME program that originated in England. However, due to the limited time of this study, the intervention involved only 16 thinking lessons, adapted and modified from *Thinking Maths* (Adhami & Shayer, 2007) and were delivered over eight months (March – October, 2014). Usually each activity was intended to replace the ordinary mathematics lesson every two weeks throughout the intervention. Each lesson focused on specific reasoning patterns or schemata (see Section 2.5 of Chapter 2 for more details on schemata) including controlling variables, ratio and proportionality, probability and correlation, and the use of abstract models to explain and predict. Within these 16 lessons, some of the lessons spiralled through increasing levels of complexity that were related to the reasoning patterns.

Table 3.3 Teaching phases with theoretical principles (pillars)

Teaching Phases	Theoretical Principles
1. Whole class concrete preparation	Concrete Preparation
2. Small group collaborative learning	Cognitive Conflict, Construction, Metacognition
3. Whole class collaborative learning	Construction, Metacognition, Bridging

Each of the 16 lesson activities were structured in three episodes and each episode consisted of three teaching phases. The episodes were designed so that students with a wide range of cognitive achievements could each make some progress during the lesson. However, the timing for each episode was suggested assuming students were at the level of mid-range achievement. The three teaching phases for each episode emphasize the five theoretical principles of Piaget and Vygotsky, concrete preparation, cognitive conflict, construction, metacognition, and bridging (refers to Table 3.3). More information on these five principles were in Section 2.5.1 of Chapter 2.

In the first phase (time allocation: 8–10 mins), the focus was on ‘whole class concrete preparation’ where the mathematical context of the activity was introduced at a level that could be understood by all students. The teacher’s role was to show the task to the students

and then allow them to describe or re-express what the task was and suggest possible ways to achieve it. The teacher could record students' answers on the board and encourage questions which could help them understand what they will do in phases 2 and 3.

In the second phase, called 'small group collaborative learning' (at least 10 mins), students in groups of two to four attempted the first worksheet with the intention that each group would have something to contribute in the next phase. In this phase, students developed ideas that they could show and explain to others. The given worksheet was to focus on challenging (it was not given any value of assessment) the students' thinking, which allowed them to present all the possible ideas that they thought were related to solution of the task. The role of the teacher was to assist each group and take notes on the ideas students were generating in group discussion. The teacher then used that summary notes and invited groups to present their work in a logical order in the next phase.

In the third phase, referred to as the 'whole class collaboration learning', students' solutions from each group were shared with the whole class (at least 10 mins). In this phase, each group reported to the rest of the class the findings of their group work and discussions. In addition, students or groups could express their difficulties to the whole class, allowing the other groups to contribute to and benefit from the discussion. Typically, phase 3 led to the next episode with the learning agenda usually set at a higher academic level. All the episodes and phases were designed to facilitate an extensive range of thinking and challenges. An episode of each of the three phases of CAME is shown in Appendices A and B. In Appendix A, the lesson activity has been structured into episodes with wide levels of attainment that the students can achieve at the end of the activity. Appendix B illustrates how the episode is broken down into phases to help the teachers manage their teaching by applying the principles of Concrete Preparation, Cognitive Conflict, Construction, Metacognition, and Bridging in their teaching practice and engaging the students in their learning of mathematics.

Table 3.4 Lesson activities with the curriculum links

No.	Lesson Activity	Curriculum link	Reasoning Patterns	Term	Week
1	Number lines galore	Number system and properties, number lines	Ratio and proportionality	1	3
2	Algebra 1 and 1a	Numbers and algebra – Reasoning and justification	Classification	1	5
3	Sets and subsets	Integers, multiple, factors and primes, angle properties of triangles and quadrilaterals	Classification	1	7
4	Ladders and slides	Numbers – Multiplicative relations	Ratio and Proportionality	1	9
5	Setters and solvers	Place values and inverse number operation	Inverse proportionality	2	2
6	Text ‘n’ talk	Multiplication and algebra	Control of variables	2	4
7	Which offer shall I take?	Algebra, symbols, and algebra-graphing	Control of variables & Abstract model	2	6
8	Framed tiles	Area and perimeter in standard and non-standard units	Control of variables	2	8
9	Rectangular function	Area and perimeter – aspects of continuity	Control of variables	3	2
10	Decontamination	Angle measurement, scale measurement, and bearing	Abstract model & Ratio and proportionality	3	4
11	Tents	Measurement, π ratio and geometric reasoning	Ratio and proportionality	3	6
12	Circle functions	Area and circumference	Ratio and proportionality	3	8
13	Furniture design	Median, range, measurements of lengths	Correlation & abstract model	4	2
14	Head and tails	Data handling: probability and proportions	Probability and correlation	4	4
15	Three dice	Probability – experimental and theoretical	Probability and correlation	4	6
16	Function	Multiplicative relations and graphs	Ratio and proportionality	4	8

The selected 16 CAME lesson activities (see Table 3.4 for more details) were intended as components of the school curriculum, with one CAME lesson replacing one regular mathematics lesson every two weeks. During the intervention, teachers and participating CAME schools were asked to include these activities in their scheme of work and modify the schedule to suit their scheme for the year. All these selected lessons were connected to real life activities and also linked to the current curriculum of the participating schools. The lessons provided an opportunity for the teacher to build a new classroom culture where collaborative learning and sharing of ideas were dominant themes and learning mathematics was no longer seen as an individual activity, where students were expected to be trained in the application of formal rules and procedure.

3.3.2 Professional Development

There is a substantial body of research internationally which affirms that quality education is not possible without quality teaching (McGregor & Gunter, 2001; Ní Ríordáin, Paolucci, Amp, Apos, & O'Dwyer, 2017). Teachers, who are at the heart of every education system, learn about teaching plans and strategies during their initial preparation. The ongoing professional developments of teachers is the central element of the process and dynamic of achieving goals and targets relating to quality, access and equity in education (Ní Ríordáin et al., 2017). In order to have an effective teaching practice of the teachers with this new program, professional development training was conducted to provide assistance for the teachers in the schools to practice the CAME teaching approaches and lessons.

The design of the professional development (PD) in this study drew on the work of Adey, Hewitt, Hewitt, and Laudau (2004) as shown in Figure 3.1. The PD training started with a one-day in-service workshop with all the experimental schools' Form 2 (Year 8) mathematics teachers prior to the implementation of the CAME program in February, 2014. In this one-day PD training, teachers received the CAME materials that included the lessons' activities and worksheets. In addition, the researcher introduced the CAME teaching approach demonstrating the role of the teacher in the development of mathematical reasoning by students rather than providing fragmentary teaching. The PD was based on the Piagetian ideas of cognitive conflict and equilibration and on the Vygotskian ideas of metacognitive reflection and social

construction where social practices need to be developed not only to engage learners in activities in which they acquire knowledge, but also to engage them in activities that further their intellectual development.

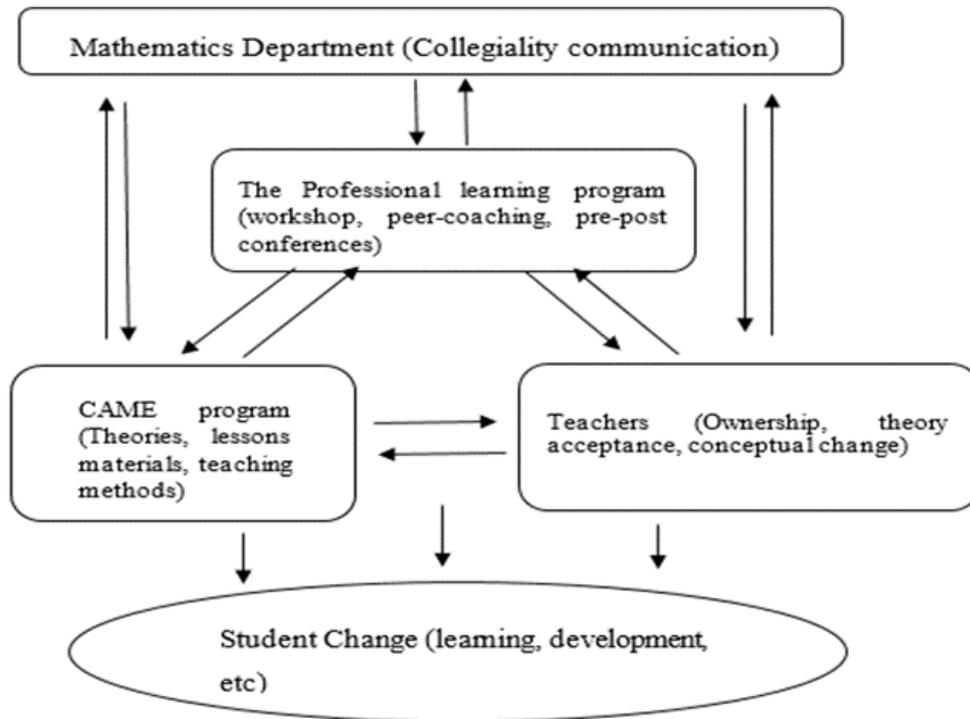


Figure 3.1 A model of successful professional development learning. (Figure credit: Adey et al. (2004))

Following the first PD, the researcher conducted ‘peer coaching’ visits to each school where he had the opportunity to hold classroom observations and teacher conferences to discuss progress in practicing the CAME lessons as well as what aspects needed to be improved for the next lessons with each of the participating teachers. Furthermore, the second and third professional development training for the experimental Form 2 mathematics teachers were held during Terms 2 and 4.

In each PD training session, teachers discussed the CAME lessons that they taught recently, compared their experiences and shared their skills; the approach was designed to help other teachers improve their teaching. A volunteer had an opportunity to teach one lesson during the PD training session while others observed and took notes for later discussion and feedback comments. The researcher then initiated the discussion of the relevant theoretical aspects of the CAME approach followed by further discussion with the rest of the teachers.

Meeting with Mathematics departments. The involvement of the whole mathematics department of the experimental schools in terms of supporting the long-term PD and intervention was necessary for conducting this research study. The first meeting with each mathematics department was a chance to show a mini-version of the first PD workshop where the researcher presented the general principles of the CAME program and the main aspects of the planned implementation. Most importantly, this gave all members of the department an opportunity to ask questions in regard to something that they were uncertain about in the new CAME program.

In each mathematics departmental meeting, the Form 2 (Year 8) CAME teachers had a chance to share, with the rest of their fellow teachers in the mathematics department, their experiences on using the CAME program in their classroom. When possible, one of the participating teachers made a short presentation about how he or she worked with students. This event allowed the rest of the teachers in the mathematics department to make comments and ask questions, which helped to improve the program as well as the teaching practice of the CAME teachers.

Peer-Coaching. A central part of the professional development workshop was designed to make the connection between teaching practice and student learning more direct and clearer. However, while the focus was on meeting the needs of students, the needs of teachers as life-long learners were also considered. Researchers in the field of professional development agree that ongoing, onsite peer coaching provides excellent opportunities for continuing discussion and change in teaching practice. Adey et al. (2004) wrote “it became very clear that the only staff development programs which were effective were those which included an element of coaching, defined as work with teachers in their own classroom” (p. 54). Research indicates that approaches such as peer coaching, study teams and peer visits were discovered to have a deep impact on a teacher’s performance in the classroom (Lu, 2010).

For this study, peer coaching with teachers was arranged and planned with all the CAME teachers. These visits included class observations and a teacher’s conference where both the researcher and the teacher evaluated the teaching as well as shared ideas to further enhance the teaching practice in order to improve students’ learning. Sometimes the Heads of Mathematics Department (HOD) were invited to join in the

class observations as well as the coaching sessions. This procedure was part of engaging the HOD as being a future mentor of the CAME program in their school.

3.3.3 Comparison group

The students at the comparison group were instructed and taught based on the regular mathematics curriculum and the textbook. At the beginning of the year, the teachers at the comparison school were given the same ‘scheme of work’ as that given to the experimental schools. This scheme of work had the list of all the Form 2 mathematics topics and content in sequence. In addition, in the scheme of work, the dates for each CAME lesson activity were highlighted, which meant that on the day on which the experimental schools switch to the CAME lesson, the comparison school continued with the normal lesson of the regular curriculum. The teachers in the comparison school were allowed to use their usual teaching strategies, and the majority of them taught by writing notes on blackboard. Teachers preferred this type of practice as they could manage to complete the syllabus required by the school administrators in time. Some of the teachers said that they did not support the idea of assigning students to work in groups. While the teachers in the experimental schools were teaching the mathematics topics and content based on the CAME teaching approaches, the teachers from the comparison school followed the lesson sequence to teach using their traditional ways – ‘blackboard and chalk’

3.4 Data Sources

This study involves both quantitative and qualitative data. Quantitative data was collected to measure the effects of the CAME program on students’ achievement, learning motivation, and self-regulation through three different instruments, including Numeracy Reasoning Task 1(NRT1), Numeracy Reasoning Task 2 (NRT2), and Students’ Adaptive Learning Engagement (SALE). Qualitative data was collected to understand the participants’ experiences with the CAME program through semi-structured interviews.

3.4.1 **Numeracy Reasoning Task 1 (NRT1) and Numeracy Reasoning Task 2 (NRT2) instruments**

For research studies with a quasi-experimental design, pre-tests and post-tests are the preferred method to compare participants groups and measure the degree of change as a result of interventions. In this study, a pre-test and post-test were used to assess the effects of the CAME program on learning of the Form 2 mathematics students in Tonga. Numeracy Reasoning Task 1 (NRT1) and Numeracy Reasoning Task 2 (NRT2) were constructed by the researcher to investigate the mathematics content knowledge, understanding and cognitive gains of the Form 2 students. These instruments both consisting of two parts (Part A: Multiple Choice and Part B: Short Answer) with 20 items (15 items in Part A and 5 items in Part B) were administered to both groups as a pre-test prior to commencing the CAME intervention and as a post-test at the end of the intervention after eight months (see Appendix C and Appendix D for the entire NRT1 and NRT2 instruments). Each instrument has 25 total scores (i.e. 1 mark for each Multiple-Choice item and 2 marks for each Short Answer item). Table 3.5 displays the contents of these two tests.

The items in both the NRT1 and NRT2 were selected from past examination papers of the Tonga Form 2 Common Examination of the government secondary schools, particularly of the years 2010, 2011, and 2012. The items in these two tests used different words and numbers but addressed the same content as judged by the researcher and three Tongan mathematics teachers. Examples of matching items from the NRT 1 and NRT 2 are shown in Table 3.6.

Table 3.5 Items matching of NRT1 and NRT2

Pre-test (NRT1)		Post-test (NRT2)		Concepts being assessed	Reasoning patterns being assessed
Item #	Q type	Item #	Q type		
1	MC	1	MC	Word number & place value	-----
2	MC	9	MC	Subtraction	-----
3	MC	16	SA	Division & Multiplication	-----
4	MC	11	MC	Time	Classification
5	MC	4	MC	Percentage & Division	Ratio and proportionality
6	MC	2	MC	Set/Venn diagram (Union and intersection)	Classification
7	MC	10	MC	Elapsed time & subtract mix-time units	Control of variables
8	MC	8	MC	Probability	Probability and correlation
9	MC	12	MC	Probability	Probability and correlation
10	MC	13	MC	Average and division	Ratio and proportionality
11	MC	14	MC	Shapes & Rotation	Abstract models
12	MC	7	MC	Number place value	-----
13	MC	5	MC	Subtract & Division	Control of variables
14	MC	15	MC	Financial – Multiplication, Division	Ratio and proportionality
15	MC	6	MC	Angles (relation)	-----
16	SA	17	SA	Pattern – sequence	Control of variables
17	SA	20	SA	Percentage, multiplication, variables	Abstract models
18	SA	19	SA	Decimal-subtraction, multiplication, division	Ratio and proportionality
19	SA	3	MC	Add & subtract like terms	Classification
20	SA	18	SA	Substitution, multiplication, division	Control of variables

**MC refers to Multiple Choice*

**SA refers to Short Answer*

The items of these two tests were face validated by the researcher and three Tongan mathematics teachers, then moderated by a panel of experienced mathematics teachers and one senior officer from the Tonga National Examination Unit (TNEU). In this process, the researcher sent the two tests (NRT1 and NRT2) to three mathematics teachers in Tonga (not teaching in the same school) requesting their feedback and comments regarding the structures of the tests and the natures of the items. In the final phase, the researcher invited again the three mathematics teachers that first involved in the first phase and one senior officer from the TNEU to join the final panel in revising these two tests. The inclusion of the senior officer from the examination unit was to get an insight into the structures, the level of difficulties, validity, and reliabilities of the tests compared to the MCE test that they designed every year for the government Form 2 students.

The Cronbach's alpha reliability coefficients of these two tests (NRT1 and NRT2) were computed using SPSS (version 22) (Pallant, 2013) for the experimental and comparison groups and were found to be 0.60 both for the NRT1 and NRT2. A value of 0.60 or higher is considered satisfactory (Adams & Wieman, 2011; Nunnally, 1978).

Table 3.6 Example of pre-test (NRT1) and post-test (NRT2) items

Pre-test (NRT1)	Post-test (NRT2)
Item 7 (Part A Multiple Choice) <i>Mele's presentation started at 9:25am, she finished at 10:12am. How long did she do her presentation?</i>	Item 10 (Part A Multiple Choice) <i>How long would Sione's flight be if it takes off at 11:15pm and lands at 5:45am the next day?</i>
Item 14 (Part A Multiple Choice) <i>When some money was shared out equally between 8 people, each person received \$9.00. If the same amount was shared between 12 people, how much money would each person receive?</i>	Item 15 (Part A Multiple Choice) <i>When some money was shared out equally between 8 people, each person received \$9.00. If the same amount was shared between 6 people, how much money would each person receive?</i>

3.4.2 Students' Adaptive Learning Engagement (SALE) instrument

This study also investigated the effect of the CAME program on students' motivation and self-regulation using the Students' Adaptive Learning Engagement (SALE) instrument (Velayutham, et al., 2011). The SALE instrument consisted of 32 items and comprised of four scales, namely; Learning Goal Orientation, Task Value, Self-

efficacy, and Self-regulation. Each scale of the SALE instrument used a five-point Likert-type response Strongly Disagree, Disagree, Not sure, Agree, to Strongly Agree (see Appendix E for the entire SALE instrument). Sample items in each scale are shown in Table 3.7

Table 3.7 SALE scales with examples of the items

Learning Goal Orientation		Task Value	
1	One of my goals is to learn new maths contents.	1	What I learnt is relevant to me.
2	One of my goals is to learn as much as I can.	2	What I learn is of practical value.
3	It is important to me that I improve my mathematical skills.	3	What I learn encourages me to think.
Self-efficacy		Self-regulation	
1	I can figure out how to do difficult work.	1	Even when the tasks are uninteresting, I keep working.
2	Even if the mathematics work is hard, I learn it.	2	I do not give up even when the work is difficult.
3	I can understand the contents taught.	3	I keep working until I finish what I am supposed to do.

Research has described Learning Goal Orientation, Task Value, and Self-efficacy as three components of motivation that have been consistently associated with students' adaptive motivational beliefs (Marcou & Philippou, 2005; Zimmerman, 2002; Zimmerman & Schunk, 2012), each of which is integral to successful engagement in self-regulated learning (see Section 2.6.1 in Chapter 2 for more details). Therefore, the corresponding three scales of this SALE instrument were regarded as the measures of the learning motivation of the students in this study.

Although the SALE was developed and administered to science students, its contents make it a good instrument to measure the motivation and self-regulation of students who learn mathematics in Tonga. In the present study, the SALE instrument was translated from English into the Tongan language to accommodate the language needs of some participants. The translating department of the Tonga Service Centre translated all the items of this instrument and it was cross-checked by two high school English teachers in Tonga to confirm the accuracy of the translation. See Appendix F for the SALE instrument in the Tongan language version.

Prior to the intervention, the modified SALE instrument (both English and Tongan versions) was pilot tested with 47 Form 2 mathematics students from two Tongan secondary schools that were not participating in the study. The purpose of this pilot study was to check the clarity and suitability of the SALE items and to eliminate ambiguities in any wording of the items. Based on the teachers' feedback, two items were re-worded to suit the students' vocabularies and understanding (see Table 3.8). Due to some teachers teaching two subjects (for example, mathematics and science or mathematics and Tongan studies) for the same Form 2 students, item #24 was revised and included the word 'mathematics' to avoid confusion among the students.

Table 3.8 Example of the revised items of the SALE instrument

Item #	Original item	Modified item
15	What I have learnt satisfies my curiosity.	What I have learnt satisfies my interest.
24	I am good at this subject.	I am good at mathematics subject.

The original study of the SALE instrument was validated with the data from a sample of 1,360 science students in 78 classes across Grade 8, 9 and 10 in 10 public schools from the Perth metropolitan area. Velayutham et al. (2011) suggest that the SALE instrument has a strong construct validity when used with lower secondary schools. The Cronbach's alpha coefficients for each SALE scale was above 0.90. The details of this original SALE instrument are found in Velayutham et al. (2011).

In this study the results of the internal consistency using the Cronbach's alpha reliability coefficient for each SALE's scales are shown in Table 3.9. This analysis was performed on data collected from 338 Form 2 students in Tonga who participated in the SALE pre-test and post-tests.

Table 3.9 Cronbach's alpha reliabilities for the scales of the SALE instrument

Scales	No. of items	Cronbach's alpha reliabilities	
		Pre-test	Post-test
Learning Goal Orientation	8	0.86	0.84
Task Value	8	0.85	0.85
Self-efficacy	8	0.85	0.83
Self-regulation	8	0.83	0.84

These Cronbach alpha coefficients displayed in Table 3.9 are all above 0.80 for both pre-test and post-test. As proposed by Nunnally (1978), reliability values above 0.60 are acceptable levels for scales when used for research purposes. Thus the reliability of the SALE with the sample of Tongan Form 2 mathematics students was confirmed, and the modified SALE could safely be used in this study to obtain feedback on how students improved their motivation and self-regulation levels during the CAME intervention.

3.4.3 Interviews

Part of the data collection involved conducting semi-structured interviews with students and teachers from both the experimental and the comparison groups. The purposes of using semi-structured interviews in this study was to gain in-depth information on perceptions, insights, attitudes, experiences, beliefs, and to gather supplementary information which could be used to triangulate or clarify any issues arising from the quantitative analysis.

One-on-one interviews were conducted with students and teachers because the participants were very concerned with their privacy. In this one-on-one situation, the participants felt free to provide responses on a wide range of issues compared to being involved in group interviews. In addition, a number of informal interviews and discussions were held with the students and teachers during the on-site visits in 2014, which assisted the implementation of the CAME program in school.

Students' interviews. Students' interviews were conducted in a small scale. A total of 16 students were interviewed – 12 students from the experimental group (4 students from each experimental group school) and 4 students from the comparison group school. Table 3.10 have the information of these interviewees. The students were chosen based on convenience sampling.

Table 3.10 Demographic profiles of the interviewees (N = 16)

School	Student Code	Gender	Age
School 1 – Experimental group	S1	M	13
	S2	M	13
	S3	F	13
	S4	F	13
School 2 – Experimental group	S5	F	13
	S6	M	13
	S7	M	14
	S8	M	13
School 3 – Experimental group	S9	M	13
	S10	F	13
	S11	F	13
	S12	M	14
School 4 – Comparison group	S13	M	13
	S14	M	13
	S15	M	13
	S16	F	13

To use the interviews to clarify and triangulate the quantitative data, most of the interview questions focussed on the same constructs (i.e., mathematics achievement, learning motivation, and learning self-regulation) that were assessed and investigated through the NRTs instruments and the SALE questionnaire. However, students in the experimental group were specifically asked additional questions in regard to their experiences participating in the CAME intervention (see Appendix G for the semi-structured interview questions for students). With respect to the privacy and for the confidence of the students, the interviews sessions were conducted in a designated room at each school.

For students' interviews, the researcher used a digital recorder to record all the interviews. The one-on-one interviews were conducted in both Tongan and English for 20 to 30 minutes, depending on how long the interviewees responded to the questions. A Tongan postgraduate student transcribed the interview data. The original transcripts were written in English and Tongan, and the Tongan transcripts were later translated into English. The transcripts, in both Tongan and English, were sent to two high school English teachers in Tonga to help ascertain the accuracy of the translation.

Teacher interviews. In the Research Question #3 of this study, the main area of interest was the teachers' perceptions of the CAME program and their understanding of the theoretical base, and so a set of the interview questions was devised. The interviews were chosen as the most appropriate way to investigate the teachers' perceptions in regard to their participation in the CAME program as well as their mathematics teaching practices (Goulding, 2002). The interviews took about 30 to 40 minutes, depending on the time constraints and the amount of detail given in the responses by the interviewed teachers. Five teachers from the experimental group and two teachers from the comparison group participated in the interviews (see Table 3.11 for the details summary of teacher interviewees). During the interviews process, the researcher first asked a set of questions on their perception on the CAME implementation and teaching mathematics, then followed by some clarifying or probing questions (see Appendix H for the entire teacher's semi-structured questions).

Table 3.11 Summary of the profiles of the teacher interviewees (N = 7)

School (Group)	Teacher Code	Gender	Teaching subject(s)	Class level
School 1 (Experimental)	T1	M	Mathematics	Forms 2 & 3
	T2	F	Mathematics & Tongan Study	Form 2
School 2 (Experimental)	T3	F	Mathematics	Forms 2 & 3
School 3 (Experimental)	T4	M	Maths & Science	Form 2
	T5	F	Mathematics & Science	Forms 2 Form 1
School 4 (Comparison)	T6	F	Mathematics	Forms 1 & 2
	T7	M	Mathematics	Form 2

Unlike the students' interviews, the teachers were not willing to allow audio-recording of their interviews. In this case, the researcher asked the questions and wrote the teachers' answers on a piece of paper. During the interviews, the researcher summarized what the teachers were saying and then read out the summary to the teacher to ensure that the intended message was being captured. Similar to the students' interviews, the teachers' interviews were conducted in both Tongan language and English in their own classroom during their preparation period. The researcher translated the Tongan transcripts into English then it was double-checked by a Tongan

postgraduate student to ascertain the accuracy and consistency of the translation. Once the transcripts and translation were confirmed to be correct, the researcher proceeded to do member checks by phone calls with the interviewed teachers to review a draft of their responses. When the draft result was confirmed to be correct, the researcher then continued into analysing the transcripts.

3.4.4 Classroom Observations

The classroom observation for each mathematics teacher was included in the data collection to understand how the participating teachers teach mathematics with or without the CAME program as well as how the students interacted in their learning process. The researcher and the teachers agreed to have four classroom observations for each teacher in the experimental group and three observations for each teacher in the comparison group. The observations schedule was designed as each teacher should have their first observation during the first month (March, 2014) of the intervention and last observation close to the end of the intervention. This was to enable the researcher to observe and compare what had happened in the classroom through the intervention such as changes in teachers' teaching strategies, students' interactions (both student-student and student-teacher interactions), and level of learning engagement perceived by individual students.

In every classroom observation, the researcher usually wrote notes about what had happened in each classroom. However, after every observation of the experimental group teachers, the researcher shared what had been recorded during the observation in regards to their teaching practices and students' engagement. This was a part of assisting the teachers in their teaching practices and working with the CAME program.

3.5 Data Analysis

3.5.1 Analysis of Quantitative Data

This study utilised four quantitative data sources - the pre-test and post-test of the two content knowledge tests (i.e., NRT1 and NRT2), and the pre-test and post-test of the SALE instrument.

Analyses of NRT 1 and NRT 2 instruments. All participating students' responses on the pre-test (NRT 1) and post-test (NRT 2) were entered into the SPSS software (Pallant, 2013). This software was used, firstly to determine the reliability of these two tests and secondly to analyse the students' performance on each test and compare the means and standard deviations between these two tests. An independent t-test analyses of the pre-test was conducted to establish the comparability of these two groups prior to the CAME intervention. At the end of the intervention, a paired sample t-test was conducted to investigate the level of improvement in students' performance from the pre-test to the post-test in each group. Based on two-tailed test, *p*-values were calculated.

Analyses of the SALE instrument. The researcher used Microsoft Excel to organize the data then exported the file to SPSS for analysis. The SPSS software was used to determine the reliability of this instrument in the context of Tongan students and obtain information about the means and standard deviations of all four scales in the pre- and post-tests to ascertain changes in students' answers with respect to the four scales. An independent t-test analysis of pre-test results was used to explore differences between the experimental group and the comparison group before the intervention. For each group, a paired samples t-test analyses were conducted to investigate and compare the changes between the pre-test and post-test performance of students in each group. Again, *p*-values were calculated based on two-tailed test.

3.5.2 **Analysis of Qualitative Data**

The analysis of qualitative data was conducted based on the method advocated by Creswell and Clark (2008) - prepare the data for analysis, acquire a general sense of the data, and the process of coding and representing themes. These steps are discussed in this section.

Preparing data for analysis: The researcher organized all the data that had been collected during the study and saved them to the computer so that the data could be easily accessed for analysis. The audio recordings from the students' interviews were transcribed, typed in a Microsoft Word document, and saved in a specific folder. The teachers' interviews were also typed into a Microsoft Word document and also saved

in a specific folder. All data collected were labelled and transferred in digital form so that researcher could easily access to it.

Acquire general sense of the data: Once the data were transcribed, organised and prepared for analysis, the researcher studied the content to get some general sense of the data. This process was done by reading the data and listening to the audio-recordings several times. Exploring all the data allowed the researcher to locate some field notes, review the organisation of the data, identify key points, focus on certain issues, and consider whether or not more data were required (Creswell, 2012).

Process of coding and representing themes: Coding is the process of segmenting and labelling texts or images to form descriptions and a broad themes from the data so that the data are more manageable (Creswell, 2012). The process of coding and selecting themes of this interview data were in two phases. In the first phase, the researcher used content analysis and thematic coding by repeatedly reading the transcripts and repeatedly listening to the audiotapes to identify codes, themes, and ideas that were relevant to the research questions. To enhance the accuracy of the interview analyses in this phase, three methods were used: (1) researcher triangulation, (2) member-checking, and (3) engaging another PhD student to critically question the researcher's coding and analysis. In regard to method number (3), the researcher analysed the data independently and then allowed another PhD student to re-evaluate and reflect on the analysis by reading some of the transcripts and the analysed that had made as a form of researcher triangulation.

In the second phase, the researcher used NVivo 10 software to analyse the collected data. The idea of using the NVivo is to help clarify the accuracy and unbiased nature of the analysis done in phase 1. The NVivo software has a complete toolkit to organise, analyse, and store different types of qualitative data (Gibbs, 2002). The researcher saved all the transcripts and the word document files directly into the internal source of the NVivo package, and then started the coding process. Through the process of coding, the developing of the themes from the data were taking place and the data became manageable. The parts that had been coded were reviewed and reread to look for consistencies and to clarify themes. Describing and developing these themes enabled the researcher to answer the research questions and write the research report.

With the observation data, the criteria for selection of this data for analysis included (a) teacher teaching practices and skills, (b) whole-class or small-group lessons in which teacher-student or student-student dialogue was prominent, (c) teaching and learning of the experimental group with the CAME lessons. All the classroom observations field notes were compiled together in a single file for analysis. The file then read and reread by the researcher to acquire a sense of the data, and key phrases and themes were marked.

3.6 Ethical Issues

This research study was given approval by the Human Research Ethics Committee of Curtin University on the 3rd October 2013 (approval code SMEC – 43 – 13). The ethical issues that were addressed in this study included informed consent, consideration, confidentiality, and acknowledgement.

All the participants in this study were provided with information about the nature and purpose of this study. It was made clear to all the participants that their involvement was voluntary and they were free to withdraw at any time. In the course of the intervention and data collection, students and teachers had minimum disruption to their normal teaching and learning activities. Teachers' conferences were held during their preparation period (free teaching periods) and their interviews were conducted at the end of the intervention.

Students were administered the tests (NRT1 and NRT2) and answered the SALE questionnaire instrument before and after the intervention program. All participants and data involved in this research are confidential and only limited to the researcher and his supervisors. Teaching and learning procedures on the CAME lessons were also not expected to disrupt the normal curriculum and students study time because of the school curriculum requirement. The participants involved in this study were acknowledged for their contribution and cooperation at the end of the CAME program intervention.

3.7 Chapter Summary

This chapter discussed the methods and analysis procedures used in this study for evaluation of the effectiveness of the CAME program implemented with Tongan

students. This chapter described the research design used in this study as well as the research questions, the participants, and the data collection methods. A brief overview of the three instruments used for collecting the data was described followed by the quantitative and qualitative data analysis methods used. The results of the analysis and interpretation of the data collected from the data sources described in this chapter are presented in the following chapter.

Chapter 4 Analysis and Results

This chapter aims to present the results and the data interpretation related to the effectiveness of the ‘Cognitive Acceleration in Mathematics Education (CAME)’ program in terms of students’ achievement, motivation and self-regulation when learning mathematics as well as teachers’ perceptions of their teaching practices.

In order to investigate the effectiveness of the CAME program in terms of students’ cognitive gains and academic achievement in mathematics (Research Question #1), students’ responses to the NRTs instruments (NRT1 and NRT2) were analysed. An independent t-test was used to explore differences between the experimental group and the comparison group. To investigate the changes of students’ performance between the pre-test and post-test in each group, a paired sample t-test was conducted. Results of the t-test analyses are provided in Section 4.1.

The students’ responses to the SALE instrument were analysed to investigate the change in students’ motivation and self-regulation levels as a result of participating in the CAME program (Research Question #2). An independent t-test analysis was used to ascertain the similarities between the experimental and the comparison groups. Changes between the pre-test and post-test scores experienced by each of the two groups were measured with paired samples t-test. A thematic coding analysis of the students’ interviews was conducted to triangulate their responses to the SALE instruments. The SALE t-test results and the students’ interview results in relation to answering Research Question #2 are reported in Section 4.2.

The third objective of this study was investigating the teachers’ perceptions of their participation in the Cognitive Acceleration in Mathematics Education (CAME) intervention program through one-on-one interviews. Thematic coding was utilised to generate patterns and themes from the data. The results are discussed in Section 4.3.

4.1 The CAME program on Students’ Academic Achievement

Having found the NTR1 and NTR2 instruments to be valid and reliable, quantitative analyses were undertaken in order to determine how effective the CAME program was

in term of students' achievement and any cognitive gains at the end of the intervention (Research Question #1).

As the baseline of students' academic achievement, NRT1 was administered prior to the implementation of the CAME program, and its results were compared between experimental and comparison group students using an independent t-test. As shown in Table 4.1, the students' performance on the NRT1 (pre-test) indicated that the experimental group ($M_{\text{exp}} = 10.23$, $SD_{\text{exp}} = 4.93$) and the comparison group ($M_{\text{comp}} = 11.31$, $SD_{\text{comp}} = 6.55$) were equivalent with no statistically significant difference ($p > 0.05$). However, after the instruction through the CAME program for eight months, those two groups' performance was statistically different in the NRT2 post-test ($p=0.000^{***}$). The experimental group scored the mean scores of 22.11 ($SD_{\text{exp}} = 6.57$) out of 25 (88%), while the comparison group scored the mean of 15.83 ($SD_{\text{comp}} = 5.11$) (i.e. 63% of the full score) on the same test.

Table 4.1 Independent t-tests results of the pre-test and the post-test for the NRTs (N = 338)

	Experimental (N = 219) M (SD)	Comparison (N = 119) M (SD)	t-test (<i>p</i>) Exp. vs. Comp.
Pre-test (NRT1)	10.23 (4.93)	11.31 (6.56)	1.70 (0.09)
Post-test (NRT2)	22.11 (6.57)	15.83 (5.11)	9.04 (0.000)***
Gain (post-pre)	11.87 (6.90)	4.52 (6.40)	9.80 (0.000)***

*** $p < 0.001$

A paired samples t-test analysis was conducted to compare the changes in students' academic achievement between pre- and post-tests for each group. Table 4.2 shows that the students in the experimental group improved their academic performance significantly ($p=0.000^{***}$) from their pre-test scores ($M_{\text{exp}} = 10.23$, 41%) to their post-test scores ($M_{\text{exp}} = 22.1$, 88%). For the comparison group, students did improve from the pre-test ($M_{\text{comp}} = 11.31$, 45%) to the post-test ($M_{\text{comp}} = 15.83$, 63%), but the increase was milder than that of the experimental group.

The effect size (Cohen's *d*) was also calculated to identify the level of impact of the CAME program compared to the traditional teaching program based on the gain scores shown in Table 4.1. The effect size (Cohen's *d*) of the experimental group as compared to comparison group was found to be 1.10. According to Cohen (1988), an effect size

of $d = 0.2$ is regarded as small, medium if $d = 0.5$ and large if $d = 0.8$. Based on these Cohen's guidelines, we can conclude that there was an extraordinarily large impact of the CAME program on improving students' performance in the experimental schools.

Table 4.2 Pre-test and post-test mean scores and effects sizes for the experimental group and comparison group

	Pre-test M (SD)	Post-test M (SD)	t-value (p) pre vs. post
Experimental group	10.23 (4.93)	22.11 (6.57)	25.45 (0.000)***
Comparison group	11.31 (6.55)	15.83 (5.11)	7.69 (0.000)***

*** $p < 0.001$

These results suggest that the experimental group students' understanding of mathematics concepts had significantly improved after the CAME program intervention, suggesting a positive impact of the CAME program on the mathematics achievement of the students. As described in Section 3.3, the experimental group teachers had practiced and guided students through the CAME program's lessons with a prescribed teaching approach while the comparison group practiced their normal tradition teaching strategies with the regular curriculum lessons. However, these findings suggest that the CAME lessons and the related teaching strategies were more effective in improving the mathematics achievement of Form 2 students compared to the traditional teaching and learning strategies.

In order to investigate whether the CAME intervention had a general effect on accelerating the cognitive development of the students, it was necessary to inspect the number of correct answers students gave for each reasoning pattern in pre- and post-tests, as described in Section 2.5.2 in Chapter 2 (see Table 3.5 for the items and given reasoning patterns). A paired samples t-test was conducted to compare the changes in each reasoning pattern between pre-test and post-test for each group. Table 4.3 shows that students in the experimental group started at a lower mean number ($M_{CVpre}=1.02$, $SD_{CVpre}=0.93$; $M_{Cpre}=0.76$, $SD_{Cpre}=0.73$; $M_{RPpre}=0.81$, $SD_{RPpre}=0.79$; $M_{PCpre}=0.47$, $SD_{PCpre}=0.56$; $M_{AMpre}=0.55$, $SD_{SDpre}=0.61$) of correct answers for pre-test NRT1 items that emphasized the reasoning patterns of the formal operational stage (see Table 3.5 for the information of the items and their corresponding emphasized reasoning patterns). However, at the end of the CAME intervention the post-test mean scores

($M_{CV_{post}}=2.13$, $SD_{CV_{post}}=1.12$; $M_{C_{post}}=1.82$, $SD_{C_{post}}=0.79$; $M_{RP_{post}}=2.07$, $SD_{RP_{post}}=1.13$; $M_{PC_{post}}=1.10$, $SD_{PC_{post}}=0.74$; $M_{AM_{post}}=1.12$, $SD_{SD_{post}}=0.74$) of the experimental group had statistically significant differences in all the five reasoning patterns that were assessed in the NRT1(pre-test) and NRT2 (post-test) tests (see Table 4.3 for the details). This result suggests that learning mathematics of the Tongan students through the CAME program helps accelerate the development of mathematics reasoning skills and thinking ability into what Piaget called the formal operational stage.

Table 4.3 Improvement in different reasoning patterns for the experimental group students (N=219)

Reasoning Patterns	Number of items	Pre-test	Post-test	t-test values (p) pre vs post
		M (SD)	M (SD)	
Control and exclusion of Variables (CV)	4	1.02(0.93)	2.13(.1.12)	12.02(0.000)***
Classification (C)	3	0.76(0.73)	1.82(0.79)	15.53(0.000)***
Ratio and Proportionality (RP)	4	0.81(0.79)	2.07(1.13)	13.91(0.000)***
Probability and Correlation (PC)	2	0.47(0.56)	1.10(0.74)	10.06(0.000)***
Abstract Models (AM)	2	0.55(0.61)	1.12(0.74)	8.74(0.000)***

***p < 0.001

On the other hand, Table 4.4 shows that the number of correct answers that the comparison group's students gave for each reasoning patterns items in the pre-test (NRT1) comparing to their answers they gave to the similar items in the post-test (NRT2) had no statistically significant differences for three types of reasoning patterns. These three reasoning patterns are; control and exclusion of variables, probability and correlation, and abstract models. However, the analysis had also found two reasoning patterns, namely; classification, ratio and proportionality to have statistically significant difference in comparing the number of correct answers that students gave for each items that emphasized these two specific reasoning patterns in the pre-test and post-test. This result indicates that the traditional teaching strategies practiced by the teachers in the comparison school and the learning activities presented to students in this group have the potential in enhancing the classification reasoning skills as well as the ratio and proportionality skills when working with mathematics task or problem-solving activities. However, the result also indicates that the traditional teaching strategies and the lesson activities practiced by many Tongan mathematics teachers are not capable in providing the students the complete required

reasoning patterns (except classification, and ratio and proportionality) which Piaget described as the reasoning skills that need to be achieved by the students in order to be in the formal operational stage (refer to Section 2.5.2 of Chapter 2 for more information). This is an evidence that there is a need for the Tongan mathematics teachers to adjust their teaching pedagogy to be more constructive such as what emphasized in the CAME program. The learning activities for the students also need to be structured so that the reasoning patterns of formal operational stage are included and been assessed during the learning process.

This result supports the hypothesis that Tongan students' cognitive ability and reasoning skills have been accelerated and enhanced by the CAME intervention. Also this result is consistent with the claim raised by Adey, Shayer, and Adhami that CASE and CAME programs have the potential to accelerate the students' cognitive development as well as improving the students' science and mathematics achievement.

Table 4.4 Improvement in different reasoning patterns for the comparison groups students (N=119)

Reasoning Patterns	Number of items	Pre-test	Post-test	t-value (<i>p</i>) pre vs post
		Mean (SD)	Mean (SD)	
Control and exclusion of Variables (CV)	4	1.18(0.99)	1.32(0.95)	1.08(0.28)
Classification (C)	3	0.95(0.87)	1.66(0.71)	7.21(0.000)***
Ratio and Proportionality (RP)	4	0.93(0.86)	1.41(0.96)	4.08(0.000)***
Probability and Correlation (PC)	2	0.78(0.76)	0.85(0.69)	0.87(0.38)
Abstract Models (AM)	2	0.59(0.68)	0.68(0.72)	1.20(0.23)

*** $p < 0.001$

4.2 The CAME program on Students' Learning Motivation and Self-regulation

As students' motivation and self-regulation also contribute to enhancing their learning, this study investigated the impact of the CAME intervention on these two aspects. The results included in this section are in response to the Research Question 2: What are the Form 2 students' motivation and self-regulation levels as a result of participating in the learning of mathematics through the CAME program?

As reported in Chapter 3, a modified version of the Students' Adaptive Learning Engagement (SALE) questionnaire was used in this study to measure the outcomes of

students' motivation and self-regulation toward learning mathematics. Three scales on the SALE (Learning Goal Orientation, Task Value, and Self-efficacy) were used to measure students' motivation (Zimmerman, 2002); one scale (Self-regulation) was used to measure the students' self-regulation. The study conducted by Velayutham, et al. (2011) provides more information about the development, characteristics, reliability and validity of the original SALE instrument. In the current study, the SALE questionnaire was administered to 338 Form 2 mathematics students in both the experimental groups and the comparison group.

Semi-structured student interviews were conducted at the end of this intervention after the SALE post-test. The main purpose of these interviews was to know more about the students' perceptions and learn more about issues that we cannot directly observe in them (e.g., their feelings, thoughts and intentions), and to find out the students' reflections in regard to their participation in the CAME intervention, including the successes and the challenges that they had experienced as a result of participating in the CAME intervention. This procedure was intended to corroborate the findings from the SALE questionnaire by clarifying any issues arising from the quantitative analysis and also to identify areas for further exploration.

In this section, the quantitative results from the SALE questionnaire are first presented followed by the analysis of the qualitative data from students' interviews.

4.2.1 **Between-group differences in motivation and self-regulation**

The Form 2 students from the experimental and comparison schools were asked about their motivation and self-regulation for learning mathematics at school. The SALE instrument was administered to these Form 2 students prior to the CAME intervention as a pre-test and after the intervention as a post-test, to investigate how the CAME program affected their learning motivation and self-regulation toward mathematics.

In order to examine the baseline of students' learning motivation (i.e. Learning Goal Orientation, Task Value, and Self-efficacy) and self-regulation, the results of the SALE pre-tests were used to compare between the experimental group and the comparison group students using an independent t-test analysis. As shown in Table 4.5, it indicated that the comparison group students had higher means ($M_{LGO} = 4.40$, $SD_{LGO} = 0.69$; $M_{TV} = 4.35$, $SD_{TV} = 0.71$; $M_{SE} = 4.33$, $SD_{SE} = 0.62$; $M_{SR} = 4.35$, SD_{SR}

= 0.56) than the experimental group ($M_{LGO} = 4.26$, $SD_{LGO} = 0.67$; $M_{TV} = 4.04$, $SD_{TV} = 0.77$; $M_{SE} = 3.93$, $SD_{SE} = 0.81$; $M_{SR} = 4.00$, $SD_{SR} = 0.74$) in all the four scales of the SALE with three scales (i.e. Task Value, Self-efficacy, and Self-regulation) had a significance differences in favour of the comparison group. These results suggested that prior to the CAME intervention, the students in the comparison group had higher level of learning motivation and self-regulation than the students in the experimental group.

Table 4.5 Independent t-tests results of the pre-tests for Experimental and Comparison groups for the SALE (N=338)

Scales	Experimental (N=219) M (SD)	Comparison (N=119) M (SD)	t-test (<i>p</i>)
Learning Goal Orientation (LGO)	4.26 (0.67)	4.40 (0.69)	-1.80 (0.07)
Task Value (TV)	4.04 (0.77)	4.35 (0.71)	-3.75 (0.000)***
Self-efficacy (SE)	3.93 (0.81)	4.33 (0.62)	-4.61 (0.000)***
Self-regulation (SR)	4.00 (0.74)	4.35 (0.56)	-4.63 (0.000)***

*** $p < 0.001$

However, after eight months of implementing the CAME program in three schools of the experimental group, the SALE post-test was administered and the results were analysed to compare these two groups using an independent t-test. As shown in Table 4.6, the independent t-test analysis showed there were statistically significant differences in the post-test mean scores on two scales of the SALE measuring Task Value and Self-regulation in favour of the students in the experimental group ($M_{TV} = 4.46$, $SD_{TV} = 0.46$; $M_{SR} = 4.37$, $SD_{SR} = 0.48$) compared to the comparison group students ($M_{TV} = 4.31$, $SD_{TV} = 0.64$; $M_{SR} = 4.22$, $SD_{SR} = 0.61$). Although there were no statistical significant differences on the post-test mean scores for the scales Learning Goal Orientation and Self-efficacy, the post-test mean scores of the experimental group students were higher than the post-test mean scores of the comparison group's students.

Table 4.6 Independent t-test results of the post-tests for Experimental and Comparison groups for the SALE (N=338).

Scales	Experimental (N=219)	Comparison (N=119)	t-test (<i>p</i>)
	M (SD)	M (SD)	
Learning Goal Orientation (LGO)	4.53 (0.47)	4.42 (0.59)	1.78 (0.08)
Task Value (TV)	4.46 (0.46)	4.31 (0.64)	2.38 (0.01)*
Self-efficacy (SE)	4.32 (0.51)	4.21 (0.63)	1.65 (0.10)
Self-regulation (SR)	4.37 (0.48)	4.22 (0.61)	2.46 (0.01)*

* $p < 0.05$

In order to compare the changes between the SALE pre-test and post-test mean scores of the experimental group and the comparison group, a paired sample t-test was conducted. As show in Table 4.7, there were statistically significant differences between the SALE pre-test and post-test mean scores of the four scales of the SALE questionnaire for students in the experimental groups. The post-test mean scores of all the four scales were significantly higher than the pre-test mean scores of the equivalent scales. These results suggest that the CAME program was effective in improving the motivation and self-regulation levels of the students in the experimental group schools.

The effect sizes of each scale were computed to understand the effects of the CAME program on students' learning motivation and self-regulation as a result of the intervention. As shown in Table 4.7, the results indicate that the CAME intervention showed a medium effect size on each of these four scales. We can conclude that the CAME program had a statistically significant and meaningful effect on students' learning motivation and self-regulation toward mathematics.

Table 4.7 Paired samples t-test analysis results of the pre-test and post-test for students in the CAME program (N=219)

Scales	Pre-test	Post-test	t-value(<i>p</i>)	Effects size (Cohen's <i>d</i>)
	M (SD)	M (SD)		
Learning Goal Orientation	4.26 (0.67)	4.53 (0.47)	5.70***	0.47
Task Value	4.04 (0.77)	4.46 (0.46)	7.81***	0.66
Self-efficacy	3.93 (0.81)	4.32 (0.51)	6.30***	0.58
Self-regulation	4.00 (0.74)	4.37 (0.48)	7.86***	0.70

*** $p < 0.001$

In contrast, there were no statistically significant differences in the post-test among the students from the comparison group. As shown in Table 4.8, the post-test mean scores for three scales (Task Value, Self-efficacy, and Self-regulation) were lower than the pre-test mean scores while one scale (Learning Goal Orientation) had a moderate increase in the post-test score but the difference was not statistically significant.

As reported in Section 3.3.3 of Chapter 3, the comparison school students were taught using only the regular curriculum provided by the government and by their teacher’s traditional teaching strategies. However, the results in Table 4.8 show that the traditional teaching approach that was used in teaching the regular mathematics curriculum by the Tongan mathematics teachers for the past few years had no effect in enhancing the students’ motivational and self-regulation levels in learning mathematics over a period of eight months. Combining the results in Table 4.7 and Table 4.8 demonstrates the effects of the CAME program using well-structured lessons and teaching pedagogy over the eight months. Overall, these quantitative findings suggest that learning mathematics using the CAME program with its designed lesson activities and instructional strategies was more effective compared to the traditional didactic teaching strategies that were used in the regular curriculum.

Table 4.8 Paired samples t-test analysis results of the pre-test and post-test for students in the comparison school (N = 119)

Scales of the SALE	Pre-test	Post-test	t-value	p
	M (SD)	M (SD)		
Learning Goal Orientation	4.40 (0.69)	4.42 (0.59)	0.31	0.760
Task Value	4.35 (0.71)	4.31 (0.64)	-0.44	0.664
Self-efficacy	4.33 (0.62)	4.21 (0.63)	-1.47	0.144
Self-regulation	4.35 (0.56)	4.22 (0.61)	-1.55	0.124

4.2.2 Students’ interviews

Students from the experimental and comparison groups were interviewed to gain more in-depth information about their perceptions toward learning mathematics. Their responses were analysed to compare with the quantitative findings from the administration of the SALE instrument in order to answer Research Question 2 of this study. There were twelve students from three schools of the experimental group and four students from the comparison group who were randomly selected for these interviews (refer to the rationale in Section 3.4 of chapter 3). All these sixteen students

were studying mathematics at the Form 2 (Year 8) level at the time of the interviews. For ethical reasons to protect their identities, these students were assigned codes S1 to S16. Table 3.10 in Section 3.4 of Chapter 3 provides a summary of the interviewees' profiles.

The analysis of the students' interviews involving the experimental group resulted in three themes; (1) a shift in students' learning behaviour, (2) the teachers' classroom management, and (3) learning approaches. Each of these themes is presented below with some responses from the students' interviews to help illustrate the theme. For more information of how these themes were analysed is described in Section 3.5 of Chapter 3.

Theme 1: Shift in students' learning behaviour

For the experimental groups, the majority of the students' responses (more than 80%) during the interviews were associated with this theme of their learning behaviour when they shared their positive experiences of learning mathematics using the CAME program and its lesson activities. Some students described their enjoyment in their mathematics classes, not just because of how the class was managed but also because of what they did in the class. They had fun with the lesson activities and they could easily understand mathematics as they worked on those fun activities. Examples of some quotes are provided below.

This year I enjoyed going to my maths class. We usually did fun and interesting activities (S11).

I find myself enjoying my maths class at the moment (S2)

I managed to understand what I have learnt in the class (S3).

These positive comments from the students indicated that the enjoyment in their learning led to better progress in their study of mathematics. Students shared their excitement about their achievements in their mathematics class, with comments like:

Last semester I got B grade in maths and it was my first time to have such a grade...I was so happy (S2).

My grade in mathematics last semester was far better than last year (S11)

I got better grade on my report card last semester compared to what I got last year in Form 1 (S12)

I feel better with my performance in maths class this year because I'm able to solve some problems when we worked in groups and also when I studied at home (S1).

The students noted that the CAME program positively influenced their learning behaviour and how they interacted with other students in class or in their group. One student mentioned that sharing with friends the problem usually helped to find the solutions for her questions

I always asked my friends to help me every time I got stuck with my maths problem. They always like to help me solve the maths problems (S10)

The findings of this theme suggest that the CAME program and its lesson activities made mathematics more fun for these students. As a result, students enjoyed learning mathematics regardless of its complexity and difficulty. The enjoyment and fun while learning mathematics led students to higher achievement in mathematics. In addition, students noted that the CAME program positively influenced their learning experience and interaction with the teachers.

Alternatively, students in the comparison group had different experiences when learning mathematics. Students S13 and S16 expressed their resistance to the type of activities that their teachers provided in class. According to student S16, her teacher preferred to select the hard activities from their textbook for the students to try out. She continued by explaining that her teacher's activities selection strategy often contributed to her struggle in learning mathematics.

After every lecture he (teacher) did in our class, he always assigned some problem-solving activities from the textbook for us to do. But most of the assigned activities were too difficult for me and my friends to solve. Usually when I don't know what to do with the problem-solving activities, I just waited until the teacher solved the activities from the board then I copy that so I can study that again at home. (S16)

However, student S15 expressed his enjoyment in learning mathematics but at the same time he suggested for more meaningful and fun activities for his class. He said “Learning mathematics is fun but it will be more fun if the learning activities are fun”.

Theme 2: Teachers’ classroom management

In this theme, students from the experimental groups shared the impact of well-organized classroom management on their learning in the classroom. The teaching strategies and teachers’ behaviour in the classroom were the issues that the students frequently mentioned during their interviews. Among the students’ responses were the following positive comments:

My teacher this year was also my maths teacher last year in Form 1, but the way she taught us this year was much different from what I experienced last year. She’s fun and she always helped and supported me every time I asked her a question (S1)

I like how she taught us, she explained the lessons slowly (S12)

I didn’t like mathematics since I was in primary school, but now mathematics is kind of my favourite subject just because I like my teacher’s way of teaching (S2)

I’m not strong in mathematics but I still love to study that subject because I enjoyed the activities that we learnt in class and I like how my teacher explained them (S7)

Some students reflected on their experiences of how their teacher’s behaviour in the class changed their views toward mathematics. Despite the complexity of learning mathematics, students still enjoyed learning mathematics because of their teacher’s behaviour. This was demonstrated in the following comments:

I enjoy my class because my teacher is very nice and I can easily understand his teaching (S4)

My teacher always came to class prepared....he explained the lesson very clearly (S6)

My teacher is fun. He’s so kind to me every time I asked him a question (S5)

Assigning the students to work in groups is a teaching strategy that the CAME program emphasized. The idea was that solving problems in a group has the potential to foster positive affective behaviour and improved cognition and metacognition functions. Students in the experimental group shared their experiences with their peers and responded to their discussions in the group. Some of the examples of their comments are as follows;

We mostly worked in groups... We shared ideas, we argued sometimes but at the end we were able to understand (S9)

He always assigned us to work in group...in class, we love to share and talk and discuss the activities (S3)

I had a lot of fun every time when we worked in groups. And one best part was when I was able to do something right in my group and they praised me (S4)

In contrast, when students in the comparison group reflected on their experiences of learning mathematics, they were critical of their teacher's way of teaching. Below are few of the students' comments.

My goal is to do better in mathematics this year, but I can't because I hardly understand my teacher's teaching (S14)

I like working in a group. We always work in groups in my science class. But in my maths class, we hardly do that. We mostly copied notes from the board and worked individually (S16)

The response from Student S14 revealed that there are more students in school who want to be successful in mathematics but that the teaching style of their teacher becomes the primary obstacle of their success. Student S16 had a similar problem. She enjoyed her science class because they were allowed to work in groups where they had the opportunity to share their ideas and develop their understanding. However, in her mathematics class she felt isolated and alone. She understood the advantage of working in groups and she wished for that advantage to be provided in her mathematics class.

The findings in this theme indicate that group problem-solving can counter poor mathematics problem-solving skills, provide motivation and peer support, raise discussion and facilitate collaboration. These findings also indicate that the students can only learn and like the subject if they like the teacher in terms of the teaching pedagogy and the teacher's behaviour towards them.

Theme 3: Learning Approaches

For students on the experimental groups, when asked about the influence of the CAME intervention on their learning motivation and self-regulation toward mathematics, more than 80% of the students responded positively. They demonstrated evidence of their self-regulation and motivation on their learning in the classroom as well as at home. The students had developed the behaviour of learning ownership by taking the responsibility to be successful in their learning. Examples of their responses are listed below:

Some activities were hard for me but I tried to solve them (S2)

Maths is one of the subjects that I study every night at home...I like this program, its makes me like mathematics more (S11)

I felt much more comfortable inside the classroom while I was doing my mathematics test (S1)

I do believe that I will get a better grade this year (S5)

Some students emphasized the lesson activities as an aspect that transformed their views toward mathematics. Indeed, the classroom that consisted of well-designed lesson activities conveyed with meaningful teaching strategies resulted in changes in students' learning approaches toward the subject matter, as indicated by the following comments:

I always find the activities to be interesting and that has convinced me not only to like maths but to study maths at home (S5)

Most of our class activities were practical and looked easy when my teacher explained. That makes me like math (S6)

However, a minority (less than 20%) of students had different views:

Most of the time I didn't understand what we were doing in class...I didn't like some of the activities because they were so difficult for me (S7)

I can't tell the difference between what I did last year and the things we did this year (S8)

In contrast, students at the comparison school had mixed feelings when they were asked to reflect on teaching and their learning of mathematics in their class. Indeed although this school had not participated in the CAME program student S15 believed that what he learned and was taught in his mathematics class helped him to set goals for his future career. He said:

I enjoy learning mathematics in my class. Much of what I want to be in the future is related to mathematics, so I always tried hard to do well in maths (S15).

According to S15, his interest in learning mathematics makes him to be one of the top mathematics students in his class.

However, students S13, S14, and S16 had dissimilar responses. They were not interested in learning mathematics. For example, student S13 commented;

I feel like I don't really learn something in the class. Even when we do the lesson activities in groups, sometime I feel like I am not learning as much as I would be if I was doing it by myself. (S13)

Overall in this theme, the interview data seem to support some of the findings from the quantitative data. In the interviews, the experimental group of students revealed that they were now more positive in terms of their commitment, self-regulation, motivation, and determination towards their learning of mathematics.

4.2.3 **Summary**

The second research question investigated the effects of the CAME program on students' learning motivation and self-regulation using quantitative and qualitative methods. The quantitative data from the SALE instrument were first analysed followed by the analyses of the students' interviews.

The post-test mean scores of all the four scales of the SALE were significantly higher than the pre-test mean scores of the corresponding scales in the experimental group (see Table 4.7 and Table 4.8), suggesting that the lessons and the prescribed teaching strategies provided by the CAME program had a positive impact on students' learning motivation as well as students' self-regulated learning. An independent t-test results to compare the mean scores differences (posttest – pretest) between the experimental group and the comparison group (see Table 4.5 and Table 4.6) indicated that there were statistically significant differences on each scale of the SALE with the experimental group having higher gains than the comparison group. The results suggested that the CAME program was more effective on improving the level of learning motivation and self-regulation of the Form 2 mathematics students than the traditional teaching program and the lessons that were practiced by many teachers in Tonga.

The qualitative analysis of the semi-structured student interviews also indicated the positive impact of the CAME intervention on students' learning motivation and self-regulation in mathematics. Students reported an improvement in their learning behaviour when they actively participated and interacted with other students in the group or in the whole class discussion. Students also reported the effects of the CAME lesson activities and their teachers teaching behaviour in improving their views and approaches toward mathematics subject. The findings of the analyses of students' interviews supported the findings that arose from the SALE instrument confirming that the CAME program had improved the level of students' learning motivation and self-regulation for the Tongan Form 2 mathematics. In fact, the improvement of these two learning aspects had contributed to the gains in students' achievement and cognition (as described in Section 4.2) as well as change in students view toward mathematics.

4.3 Teachers' interview and Classroom observations

This section presents the results of the responses and perceptions of teachers who participated in the CAME program in these three schools and responses from teachers in the comparison school. The analysis of the interviews sought answers to Research Question 3: What are the teachers' perceptions of their participation in the Cognitive Acceleration in Mathematics Education (CAME) intervention program?

Over a decade struggling with how to improve students' low performance in mathematics, the Ministry of Education and Training in Tonga proposed a revised curriculum with the aim of moving the mathematics learning approaches towards a more constructivist view of education (Ministry of Education and Training, 2014). In particular, the Ministry of Education and Training in Tonga wanted a teaching and learning mathematics program that encouraged the transition from a teaching procedural knowledge approach to a constructivist approach where learning is focussed on conceptual understanding and constructive ideas. Also, the Ministry of Education wanted the learning program to foster the development of thinking skills through the learning activities and the teaching pedagogies. In addition, the Board of Education wanted a program that could be practical, suitable for mixed-ability classes, and which could easily be implemented by practicing teachers and not compromising mathematical rigour. To initiate the educational reformation, in 2011 the Minister of Education and Training invited all the mathematics teachers in the Tonga secondary school to participate in a six months professional learning training conducted by the Ministry of Education and Training in partnership with the University of the South Pacific (USP). The aims of these professional learning workshops were to provide supports to mathematics teachers in terms of mathematical contents and pedagogical knowledge.

In addition, the Ministry of Education and Training has undergone a major revision of the mathematics curriculum of the secondary school levels as part of the educational reform. The mathematics syllabus for Form 1 to Form 3 was reviewed in 2012. The Form 4 syllabus was reviewed in 2013 and was on trial in 2014 and 2015. For Forms 5, 6, and 7, the mathematics syllabus was proposed to be reviewed in 2016 or 2017 (Ministry of Education and Training, 2014).

Although the Ministry of Education implemented these changes and reforms in the mathematics curriculum, the search for a better learning and teaching program that can effectively accommodate and facilitate mathematics learning of the Tongan students is still in progress. As a result, taking into consideration this issue, the current study involving CAME was introduced in three secondary schools in Tonga in 2014 to address these concerns. The comparison school in this study could be seen as the status

of the existing initiative of the 2012 curriculum reform introduced by the Ministry of Education and Training.

4.3.1 **Teachers' interview**

To determine the effectiveness of this program, this study also investigated the perceptions of teachers regarding their teaching practices in the CAME program intervention. The profiles of the teachers who were selected for the interview are summarised in Table 3.11 in Section 3.4 of Chapter 3. To protect their anonymity, these teachers were assigned codes T1 to T7. The analysis resulted in three themes: (1) Teaching pedagogy transition, (2) Students' learning transformation, and (3) Suitability for the learning needs of students. The method of how these themes were analysed and identified are described in Section 3.5 of Chapter 3. These three themes are presented below and are illustrated with some excerpts from teachers' interviews from both the experimental schools and the comparison school.

Theme 1: Teaching pedagogy transition

Positive comments: The first theme that emerged from the teachers' interview data was that the teachers in the experimental schools felt that their teaching pedagogy had been positively affected by participation in the CAME program intervention. One teacher described this pedagogical transition as "breaking the boundaries that isolated the students". These teachers described that their participation in the CAME intervention provided an opportunity to develop certain teaching strategies and skills that otherwise would not have occurred. For example, T2 from school 1 (experimental school) shared the influence of the CAME program on his teaching skills after being trapped in the same teaching strategy for over 15 years;

...the pedagogy that was emphasized by the CAME program, I believe that is the latest skills that I have learnt in my teaching career, especially in how to involve the low achievers to engage in the group and class discussion (T2)

T3 from school 2 (experimental school) shared similar experience;

There are a lot of things that this program (CAME) helped me as a teacher...its structures and teaching approaches were new, very new but I found that my students easily understood maths when I taught my classes with those teaching approaches and materials (T3)

Some teachers shared their experiences of how their questioning techniques had improved throughout the intervention. They shared that having asked a question during the activity, students tended to remain silent most of the time before they responded. The tendency to 'provide the answer' was very tempting but teachers had to hold back that emotion and allowed the students initiate the reply. Most teachers in the experimental schools explained that their disadvantaged students participated in group activities very often. They believed that the improvement of their questioning skills had played a major role in the students' engagement, particularly the learning disadvantaged students. An example of a quote by teacher T5 from school 3 (experimental school) was:

Initially, every time I asked them (the learning disadvantaged students) a question it took a few minutes before someone made some response, and most of the time I provided the answers...As I learned about metacognition and cognitive conflict, I felt that my questioning skills had improved. I knew what questions to ask, and when to ask. A few months ago, I noticed these students were actively involved in our whole class discussion, they shared their answers and ideas with the rest of the class (T5)

Another teacher from school 1 shared that the improvement of his questioning skills had helped him as a teacher to always create space and allow time for the students to re-think and reflect on their initial ideas or answers.

...once the students replied to a question, I usually asked; Why do you think that way? Is there any other way that we can use? What makes you feel that this is it? For me, asking these questions opened up a space for them to give more for their initial answer and it was always interesting when I listened to how they put their thoughts together (T2)

We cannot see into the minds of our students to know what they need or understand. Observing their actions and listening to their talks are the ways to gather information

that we could use to predict and approximate what they had understood. However, according to these teachers, it is hard in the Tongan regular classroom to retrieve such information as students are mostly remain quiet and are being shy do not share their ideas. T4 from school 3 (experimental school) had shared his experiences that learning to identify the students' level of cognition and to encourage students to engage in class discussions required some skills in questioning the students. He explained:

Trying to know what the students understand or do not understand during the lesson is so difficult for us as teachers because students sometimes are afraid or shy to speak or share their ideas (which is normal for our Tongan students)...if the teacher has good questioning skills, he/she can use those skills to remove any anxiety among the students and establish an environment where students can be confident to share their ideas or post a question (T4).

Some teachers compared the CAME program and the Sheltered Instruction Observation Protocol (SIOP) model, a teaching model that been practiced by these three experimental schools for almost ten years now. According to these teachers, they felt that 'CAME is simpler and very specific with mathematics'.

Negative comments: Despite these positive responses and comments, there were some negative comments related to the structures and transferability of the CAME program. T5 from school 3 believed that the teaching strategies that were required by the CAME program were so difficult to learn, especially working with students on the meta-cognitive aspects of the activities. She elaborated that:

I tried to follow through with these five principles in my teaching practice, it took me couple of weeks before I managed to control my students as well as my teaching (T5)

She explained that the CAME program will be more difficult for new mathematics teachers or less experienced teachers.

The biggest problem associated with adopting the CAME program in these three experimental schools was the amount of preparation time needed by the teachers to ensure a successful lesson. All these CAME teachers commented on the time

allocation for the CAME activities. These activities were too long for one session; it usually took two to three sessions in order to complete one activity. Their concerns were related to the tension of completing their regular Form 2 mathematics curriculum as required by their school administrators.

It was evident in the interviews that one of the main strengths of the CAME program in these schools was the development of the teachers' questioning skills when teachers practiced metacognitive principles in their teaching pedagogy. As most of the participating teachers were teaching two subjects (for example: mathematics and science) or two levels (for example: Form 2 and Form 3 or Form 2 and Form 1), they had extended the practice of the CAME teaching pedagogies and questioning skills into their other classes or subjects that were not involved in the CAME program.

Theme 2: Students' learning transformation

The second theme that emerged from the teachers' interview data was the shift in the students' learning behaviour and strategies. Teacher T1 from School 1 (experimental school) explained that since he practiced the CAME teaching strategies and learned about its lesson activities, he realised his students were more engaged and participated in their lessons. He said that students were able to speak to their group members and shared their ideas (which often did not happen before). He continued to say that this was not something that usually happened with these students who were his students in Form 1 (Year 7) the previous year.

Most of these students were in my Form 1 mathematics class last year and according to what I recalled from last year, mathematics was one of their weakest subjects. But since CAME lessons and activities were implemented in my class this year, I found my students to be more engaged in their studies and they improved in their achievement and learning behaviour as well (T1)

He also reflected on how this program impacted on students' attendance. He said that motivating the students (especially the learning disadvantaged students) to regularly attend the class was not an easy task to do in this school. But implementing the CAME program in his class, the attendance of the students improved. He said

My class attendance had improved lately because they always look forward to come to my maths classes. Recently I spoke to the Form 2 English teacher - she was frustrated with these students (she mentioned their names) because they always missed her class. But then she was surprised when I told her that those students that she had named were attending my class those days, and they usually came to my class regularly (T1).

This teacher (T1) realised that the best way to motivate the students was to teach them using meaningful teaching strategies with meaningful lesson activities. Similarly, another teacher shared the same experience of how the CAME program influenced the attendance of his learning disadvantaged students:

I believe this CAME intervention is distinctive because its lesson activities with its teaching strategies easily motivated my students to be engaged and to learn maths...my students who are not really strong in mathematics rarely missed the class. They like doing the CAME activities as well as some other maths activities in the class (T4).

Teacher T3 from school 2 (experimental school) described the determination, commitment and self-regulation that students had in trying to work out the given lesson activities, when she commented:

The lesson activities looked easy for some students but as they start to work on them, they found them to be challenging. But the good thing was that most of them they kept being engaged with the problem activities with their friends until they came up with something (T3)

The same teacher explained that with the commitment and determination of her students, they “enjoyed the chance to help each other” and they were “more open to their friends” especially during group discussions.

One issue that most teachers discussed in the interviews was the idea of not marking or grading the students’ work when they worked out the lesson activities. According to these teachers, they always tried to give grades for work that their students did in class. Either with homework, assignments, or group work activities, the teacher always tried to give some marks for such work. Teacher T3 from school 2 (experimental

school) expressed her opinion that the feelings of competition and self-centredness were very dominant within the students' psychology, particularly among the more capable students. Indeed, the less capable students were isolated in the classroom especially in group work discussions and sharing. However, the CAME intervention required the teachers to not give any marks for the work that students did during the CAME lessons but allowed them to discuss and share their ideas. Some teachers shared their experiences of how the learning styles of their students changed when they knew that their work would not be marked. For example, teacher T3 commented:

I usually informed them at the beginning of the session that this activity was not to be marked...As I observed them, I then noticed how active and involved they were in their discussions and while doing their work. They usually debated and argued about their answers but at the end I knew they enjoyed their learning (T3)

Similarly, teacher T2 from school 1 (experimental school) described her experiences of how the changing of classroom culture positively affected the learning and performance of the students:

...students were freer to learn and acted upon their ideas with open minds knowing they would not be marked and it would not affect their overall class performance grades or marks. They were also open to sharing their opinions with each other and the teacher because they knew that if they make mistakes, the teacher would correct them; again it would not affect their overall grades (T2).

In contrast, teachers at school 4 (the comparison school) shared their disappointments and frustrations when trying to motivate the students to be actively engaged in their learning. Teacher T6 from school 4 reported that in her Form 2 mathematics class only two students consistently engaged in every work task they did in class; the majority of the students were doing their own things and did not pay attention in class.

Teaching mathematics to this group of students is not that easy. The majority of them do not really know how to solve the basic algebra or algorithm problems. In that case, I had a hard time trying to engage them to participate in class problem-solving activities or discussion. In addition, they don't even pay attention in class, except two students, a boy who just transferred from Tonga High School (government school) last term and one girl who is really committed to her study. These two students always concentrated in doing their class work (T6).

When asked about the possible solution that she thought may help solve her students' learning problem in mathematics, T6 suggested a better learning program with well-designed mathematics curriculum to be implemented in the school. She said that she was teaching mathematics for Form 2 and Form 3 for over 16 years and she is still using the same curriculum that she was using in her first year of teaching. Teacher T7 of school 4 had similar experiences with students being disengaged in most of the class lesson activities, but he suggested that professional development training by experts will help them improve their teaching strategies, especially for teaching the learning disadvantaged students in mathematics.

The findings under this second theme indicate that the CAME intervention program resulted in students perceiving a transformation in their learning strategies and behaviours. For example, the students found themselves to be more engaged in learning mathematics and regularly attended classes despite the complexity of some of the activities. The teachers recognised that the strategy of grading or marking the students' work frequently prevented students from being active learners. Comparing the responses between the teachers at the experimental schools with the teachers at the comparison school, there is sufficient evidence to claim that the CAME program had benefited the students as well as the teachers in the experimental schools.

Theme 3: Suitability for the learning needs of students

In discussing the structures of the CAME material and its suitability for students' thinking ability ranges, most teachers expressed their views that students at the average ability level and students who were regarded as the low achievers would benefit the most from the program. Most of the lesson materials and activities were at their level

of mathematical understanding. Two teachers from the same school had reflected on their experiences of teaching their students with these CAME activities;

...I think the first feature that impressed me a lot was the lesson activities. The episode structures and how they were designed were easy for my students to follow and to learn the required concepts (T1)

...dividing a single activity into episodes and phases helped my students constructing their conceptual knowledge to the required levels that were expected to be achieved in the lessons...the activities seemed to capture the attention of my students. I noticed that every time we did the activities given in the CAME pamphlet, the students were engaged and were active in their various groups. It gave me the idea to re-design similar activities to use on other topics (T4)

These teachers also reflected that students' engagement in the CAME activities played a major role in the development of students' confidence, it increased their level of motivation, and minimised their learning anxiety which resulted in their participation and engagement in other activities of the class. One of the teachers expressed his personal views that he saw the CAME lessons as improving the students' participation in class.

Another teacher (T2) shared the challenge that she faced in the classroom such as trying to set the lessons to match with right academic level for some of her students:

I have some students, just a few of them, who are smart in mathematics. When I gave them the CAME activities, it seemed too easy for them, particularly on the first episode of the lesson activities (T2)

This group of students seemed to be more capable in mathematics and they felt that the activities at episode 1 were too easy for them. However, teacher T2 recognised the existence of the five principles of the CAME teaching strategies and how these principles supported the designed lesson activities to suit all ability levels. She said;

...this challenge can be best done by concentrating on construction and metacognition aspects in each lesson (T2)

According to teacher T2, these higher achieving students thought that the CAME activities were too easy, but they found them to be very challenging especially the part of the activities which they were required to reflect on their problem-solving strategies and their answers.

She conceded that when students practiced the CAME lesson activities in the classroom without the teacher facilitating and guiding them as the CAME program required, those CAME lessons had no impact on students learning. She continued to say that the middle ability range and low achieving students were disengaged and felt bored during the lesson without the teacher guiding the activities. She emphasized that teaching the CAME lessons supported by the five teaching and learning principles made the lessons effective and suitable for all ability levels.

In terms of the learning opportunities by the disadvantaged and low achieving students, one teacher described her experiences in teaching this group of students with the CAME program. Her experiences were similar to some responses of her fellow teachers.

The lessons were suitable for the Form 2 students, especially with my class in which the majority are students with learning difficulties in maths. Indeed, there are a few students who still struggle in some stages. But as I evaluated what we had done so far this year, my students tended to easily learn the maths concepts by doing the CAME lessons compared to doing the lesson activities in their textbook (T5)

Most of the interviewed teachers explained that the teaching pedagogy emphasized by the CAME program was suitable for their students' learning. According to the interview responses, most of teachers highlighted the 'group work' involved in this pedagogy, allowing the students to always work in groups. Prior to the intervention, they thought that allowing the students to work in groups could result in chaos in the classroom, allowing students to cheat, the low achievers to be isolated, and it may increase in the teachers' workload during class. However, these concerns were not evident during the intervention when they worked with students on either the CAME lessons or in their regular lessons. One teacher explained that their participation in the three CAME professional development training sessions provided skills on how to

manage and supervise the students during group work. Another teacher explained that he witnessed that giving the students more time to spend discussing with their friends within groups was more effective than if he explained the lessons by himself.

I found out that students are picking up quickly the ideas when they spend more time speaking and sharing with their group members than if I explained the problem to them (T5)

Teachers from the comparison school did not have this successful experience of group work. Teacher T7 explained that every time he allowed students to work in groups, they mostly ended up complaining about unfinished group work.

The findings under this third theme indicate that the teachers in these experimental schools recognised the teaching aspects and learning environments that were appropriate for the learning of their students. For example, they recognised the importance of choosing the lesson activity that matched the cognitive ability of the students and at the same time demonstrated the required concepts that needed to be addressed. The students only learned if they liked the lessons activities. With the learning environment, these CAME teachers came to understand that when students attempted to solve mathematical problems in group situations, they displayed a variety of cognitive, psychological and sociological behaviours that were not normally overt in individual problem-solving. Also, the findings indicate that the teachers in the experimental schools were able to accommodate their teaching practices to enable the students to learn and be engaged with the principles of the CAME program such as cognitive conflict, metacognition and construction of their mathematical ideas. For example, teachers described how they ensured that all students enjoyed the given activities and their participation did not matter at what cognitive level they were; they all were encouraged to contribute and be accountable for their answers.

4.3.2 Classroom Observations

The main features of the CAME intervention program focused on formal ‘reasoning patterns’ and the use of the five ‘pillars’ of CAME in the lessons. These features were introduced during the CAME professional development workshops for the teachers from the experimental schools. The teachers in the experimental schools who attended the CAME professional development workshops were visited by the researcher at least

four times during the intervention period. The visits to these experimental schools included a classroom observation and peer coaching with teachers. Similarly, teachers from the comparison group were visited for classroom observations three times as decided by their mathematics head of department.

Teachers' lesson preparation and planning

The teachers' lesson preparation and planning was mainly assessed based on the quality of how the teacher organised the activities, the planned assessment activities, and the time allocation that was set for each part of the learning activities. In the experimental group, teachers showed improvement in the quality of their lesson preparation and planning through the four consecutive classroom observations; these observations are consistent with the findings reported in Sections 4.1, 4.2, and 4.3.1 that the CAME program enhances teaching and learning mathematics at this Form 2 level. In most lesson tasks, the teachers wanted their students to work mostly in small-group arrangements so that they could share their ideas, express their thoughts, and learn to respect their peers' ideas. Also, these lesson tasks give rise to classroom work focussed directly within the various reasoning patterns or schema. Cognitive conflict – something that does not make sense to the students – drives the discussion and students' conversations in groups. This collaborative discussion enabled the students to worked together throughout the lesson tasks as they engaged with different challenges in trying to solve the cognitive conflict. In fact, there is an inference that students had more opportunity for engagement with cognitive conflict, social construction, and metacognition as they arranged to work in small-groups. On the other hand, teachers in the comparison school usually followed the pre-planned activities in the textbook. However, as most Tonga Form 2 mathematics textbooks were designed and published in New Zealand, therefore most learning activities and examples in the textbook were based on New Zealand contexts such as people's names, places, and pictures which most students had not experienced. Nevertheless, most teachers in the comparison group did not spend enough time during their teaching to clarify these foreign contexts places and pictures to the students. In fact, it was better if the teachers replaced the names, places, and pictures (if possible) in the textbook's learning activities into similar things in their local context which are familiar to the students. However, that was not the case. Therefore it is believed that this teaching strategy of

these teachers contributed to the low performance of the comparison group's students in the NRT2 and SALE post-test. This result had been reflected in the findings found in the study conducted by Otunuku et al (2007) where they claimed that most students in Tonga performed poorly in their study due to the lack of teaching skills and content knowledge of their teachers.

In addition, the teachers in the experimental groups assessed their students by providing feedback to their written works, providing constructive and leading questions, and listening to group discussions. In fact, these forms of assessments can allow the teachers to evaluate their students' learning during the learning processes and to ensure that the students are on the right track in solving problems. Hence, both learning and teaching mathematics were enhanced. These forms of assessment with their students were also practiced by the teachers in the comparison school but it was not as effective compared to what happened in the experimental schools classrooms because most students were not engaged while doing the activities.

Students' learning activities and engagement

During the CAME lessons, each student in the classes of the experimental group were usually provided with worksheets. These students had more practical work and teacher support in their lessons compared to the normal way of teaching mathematics in Tonga. In the majority of the CAME classrooms there were more teacher-student, student-student interactions and discussions within this class than was normally the case. In each group, the members sat close together, cooperatively used one set of materials, discussed ideas and assisted the student designated as the recorder to write down their findings. In nearly all cases, the students remained in their assigned roles in their group and there was little disagreement between students when they shared their ideas (metacognition). Teachers were always walking around the groups and assisted students with some ideas and asked questions to help the students reform their ideas. Within these CAME classes the formation of groups occurred in different ways; the group formation that appeared to be favoured by most teachers in their classroom was to arrange students with mixed-ability in mathematics.

On the other hand, in the comparison school classes, the teaching strategies practiced by the teachers were very similar to the normal Tongan way of teaching and were

mainly textbook-oriented with lectures. The teachers explained the topics from the front of the classroom for about 10 – 15 minutes, then assigned some exercises from the textbook for the students to solve. The common teaching strategy practiced by teachers in the comparison school for teaching mathematics was the ‘chalk and talk’ approach where students copied the notes and examples written on the blackboard and then worked individually from their own textbook. However, in one classroom, the teacher usually assigned his students to work in groups when doing problem-solving but had to spend most of the period encouraging members to stay in their groups and concentrate on their group tasks. Students constantly complained to the teacher that other members of their group would not cooperate. Often in this classroom some students did not want to share their work with other group members. On most occasions in this classroom there appeared to be a total lack of harmony and, in one case, anger and aggression between student members of the group. It was found that some students were not engaged at all.

During the whole-class discussion sessions, the students in the CAME classrooms were very active and engaged in discussions. They posed a lot of questions to the teachers and to their classmates as they presented the results of their group work. Throughout the four classroom observations, the teachers in the experimental group exercised the metacognition principle by providing frequent opportunities for the students to engage in meaningful discourse where students taught each other, observed each other’s work, listened, asked question for clarification, justified solutions and even challenged other students’ ideas and thoughts. The idea was that a student who is on the brink of understanding will be pushed over that threshold by reflecting on the reasoning skills of peers already operating at a higher cognitive level. Through these interactions, the students work collaboratively on the resolution of the cognitive conflict and they learned to nurture their relationships among themselves by sharing their ideas, helping each other, and even motivating each other to be part of the group work. In some case, the teachers joined the small group discussion by prompting students to construct more powerful reasoning by asking some typical probing questions such as “Why do you think that way?” “Is there any evidence that can support your conclusion?” The teachers then encouraged the students to reflected on and explain their thinking to each other (metacognition) in the group as they solve the reasoning problems (cognitive conflict) or the tasks activities.

In the comparison school, on the other hand, the majority of the students did not support discussion sessions because they were either not engaged or were too shy to share their results with the rest of the class. It was observed that their teachers tried their best to engage the students in the learning activities but it seem that the students were not interested in what they were doing in the activities.

Teaching and Learning through the CAME principles

With regards to students' learning based on the five 'pillars' (principles) of cognitive acceleration, students easily adapted to the nature of cognitive preparation, cognitive conflict, and construction as well as bridging in their problem-solving and classroom learning activities. The metacognition component, however, was not easily adopted by the students at the beginning of the intervention. Students were not used to monitoring their own thinking during class activities and they often had difficulties structuring their thoughts. In the first observation in one of the CAME classrooms, the researcher often heard students say 'I don't know where to begin' and 'I'm not sure whether my answer is correct, but I don't know what else to do'. As time went by, students became familiar with the CAME procedures and learned how to resolve such difficulties. As they progressed, these students learned to share ideas by listening to other students and describing their own thoughts to others.

The last CAME principle, bridging, was mostly facilitated by worksheets covering other different fair test problems given to students as a follow-up activity or homework. In many cases, most teachers solved some of the test problems in class with the students and then encouraged the students to do the rest of the test problems from home for the next day. Adhami and Shayer (2007) regard bridging as a powerful teaching strategy. It provides concrete cues for students to keep practicing the new thinking long after the particular lesson in which learned is over. At the end of the intervention, it was observed that the majority of the students in the experimental schools had the ability to regulate and monitor their own learning, group discussion, cognitive activities, and could reflect on their actions while engaged in problem-solving.

The seven teachers who participated in the CAME intervention had taken into consideration the proficiency level of the students and made sure that the way they

presented the mathematical tasks and activities was in a language that was clear, simple and easy to comprehend. This part of teaching strategies is emphasized by the concrete preparation principle of the CAME program. In some case, teachers used the Tongan language to clarify concepts, definitions and instructions that were vague and confusing. For example, one of mathematics topics that teachers usually instructed in the Tongan language was ‘Angle measurement’. Most of the students found this topic difficult to understand when they learned that in the English language, therefore the teachers preferred to explain and discuss the concepts with the students in the Tongan language. As the CAME program progressed, it became clearer to the teachers that students could only understand the mathematical concepts if they understood the language clearly.

In the comparison group, most of the teachers practiced the same procedure by clarifying the vocabularies and technical terms of the learning activities. However, many students had difficulties to understand some words, pictures, and places used in activities of their learning textbook (the textbooks were designed and published in New Zealand). The teachers had spent a certain amount of time trying to negotiate the definition of these words with the students, but it was clear that the students had a problem with trying to internalise those concepts into their understanding.

4.3.3 **Summary**

The third research question investigated the teachers’ perceptions in regards to their practice with the CAME lessons and the prescribed teaching approach with their students in the classroom. The majority of the teachers’ responses to the CAME program were very positive, with mention being made of learning and employing new teaching skills and strategies to assist students, especially the learning disadvantaged students, to learn and enjoy mathematics. The emphasis of the CAME program was to improve the students’ academic achievement and learning approaches that involve motivation and self-regulation by improving the teaching skills of the teachers. The intervention program was well received from the teachers and students. Teachers reported the positive transition of their teaching pedagogy which was suitable to the learning styles of their students. As a result a positive shift in students’ learning behaviour and strategies was identified during the CAME intervention.

Chapter 5 Discussion and Conclusion

5.1 Introduction

The previous chapter presented the results of this research in relation to each of the research questions. The purpose of this final chapter is to synthesize those results with the literature to answer the three research questions addressed in chapter 1, to summarize the main findings of this study, and to discuss the results in terms of learning and teaching of mathematics in the secondary schools in Tonga using the Cognitive Acceleration in Mathematics Education materials. The significance and limitations of the study are also discussed and some implications and suggestions made for further research and teaching in this area.

Section 5.2 outlines the summary of every chapter of the thesis. Section 5.3 discusses the main findings from the three research questions of the study. Section 5.4 describes the implications of the study, Section 5.5 detailed the limitations that appeared in conducting this research study, Section 5.6 reviews issues for future research, and Section 5.7 concludes the chapter with a summary.

5.2 Thesis summary

The purpose of this study was to investigate the outcomes of implementing the Cognitive Acceleration in Mathematics Education (CAME) program in 13, Form 2 Mathematics classes in three secondary schools in Tonga. The study examined the effects of the CAME program on students' academic achievement, students' learning motivation, and students' self-regulated learning. Also, the study examined teachers' perceptions of their participation in the CAME intervention. The decision to implement this program was demonstrated by concerns that traditional teaching of mathematics in the secondary schools in Tonga was not meeting the educational needs of the students. An increasing number of students in high school had poor mathematics skills which led to their low mathematics achievement. A number of research studies have focussed on improving students' thinking ability and problem-solving skills like CAME, mainly to improve students' academic achievement and understanding. Further, many studies have suggested that there is a positive relationship between

motivational beliefs, self-regulation, and academic performance on students' learning (Mega, Ronconi, & De Beni, 2014; Wolters, 1999). Therefore, the focus of the study included an investigation of the effects of the CAME program on students' achievement and the influence on students' learning motivation and self-regulation as well as teaching pedagogies of the teachers. The Numeracy Reasoning Tasks (NRT1 and NRT2) instruments were developed to investigate the students' achievement and understanding and the Students' Adaptive Learning Engagement (SALE) instrument was administered to explore the effects on students' learning motivation and self-regulation followed by students and teachers semi-structured interviews in regards to their participation in the CAME intervention.

In chapter 1 of this thesis, the background, rationale, research aims, and significance of this study to investigate the CAME program in Form 2 students in Tonga were described. The objectives and research questions of the study were outlined.

Chapter 2 reviewed the literature regarding recent studies on cognitive acceleration programs and the theories and theoretical framework that underline the philosophy of the CAME program. Since the study followed students' mathematics performance in the CAME schools, an overview of the related research on the origin and development of the CAME program, the theoretical framework that underpin the CAME program as well as the students' learning motivation and self-regulation in relation to students' achievement were presented.

Chapter 3 described the methodology and the research design used in this study, a description of the students and teachers (both in the experimental and comparison schools) who participated, and the details of the instruments used to collect data. The designed lessons based on the theoretical framework of the CAME program also were described. As described in Chapter 3, this study employed a quasi-experimental research design combining quantitative and qualitative data to determine the effectiveness of the CAME program in terms of students' achievement, students' learning motivation and self-regulation, and teachers' teaching practice. Quantitative data were analysed using IBM SPSS v 22 (Pallant, 2013). The qualitative data were analysed in two phases; firstly by thematic coding followed by the researcher's triangulation and secondly by using NVivo 10 as to enhance the accuracy of the analyses (Castleberry, 2014). Data obtained from the NRT1 and NRT2 were analysed

to respond to Research Question 1. The data obtained from the SALE instrument, semi-structured students' interviews and classroom observations were analysed to answer Research Question 2. For answering Research Question 3, the data were collected from seven teachers' interviews, namely, five teachers from the experimental group and two teachers from the comparison group.

Chapter 4 presented the results and findings of this study and response to the three research questions. This final chapter provides a summary of the findings for each research questions. Implications, limitations of this study and recommendations for future research and teaching are also provided.

5.3 Major findings

The following sections present the findings of the study in the context of each research question.

5.3.1 Research Question 1

To what extent does the CAME program change Tongan Year 8 (Form 2) students' academic achievement in mathematics?

This research question was concerned with students' performance and achievement as a result of their participation in the CAME program intervention. Data were analysed and reported in Section 4.2 of Chapter 4. Results from this CAME program intervention showed positive effects on students' levels of thinking and mathematics achievement within the experimental group compared to students' performance in the comparison group. The independent and paired sample t-tests results of NRTs (NRT1 and NRT2) indicated that students in the experimental group made significant cognitive gains and achievement over the eight months of the intervention (see Table 4.1 and Table 4.2 of Chapter 4 for the results). These students had started with lower mean scores prior to the intervention, but their final scores in the post-test were much higher compared to students' performance in the comparison group. The effect size of 2.04 (see Table 4.2) for the NRTs shows that the CAME program intervention based on the teaching approach and the classroom thinking-lesson activities were broadly highly successful in improving the mathematical conceptual understanding and achievement of the Tongan students.

Looking at these results, it is relevant to consider how such improvement in students' thinking and improvement of students' achievement was brought about. Firstly, the modified 16 selected lesson activities from the *Thinking Maths: Cognitive Acceleration in Mathematics Education* (Adhami & Shayer, 2007) were developed to give rise to classroom work that focussed directly within the five pillars, the reasoning patterns, and the conceptual understanding of the problem. Within these 16 selected lesson activities, compared to the existing curriculum, tasks are more conceptual, more problem-solving skills are required, more desirable higher-level reasoning and critical thinking and more creativity is needed; it is also evident that what is being learned is relevant to the real world. In addition, the success of conducting these lessons in the classroom is based on the teacher's preparation and the cognitive conflict set within specific schemata (or reasoning pattern), the teaching pedagogy (including teacher's questioning technique) used to guide the students' ideas in the group or during whole class discussion, and students' development of metacognition.

In this case, the role of the teacher changed from class director to a facilitator of the learning activities such as prompting students to consider the ideas that emerged from their earlier discussion and to ascertain if there were other ways of solving the problem. In addition, students were encouraged to reflect on their problem-solving strategies, through asking the students to justify their answers (solutions), describe how they arrived at the answers, and describe any problems they encountered in evaluating their learning. This teaching strategy is believed to foster the development of metacognition which is an essential part of cognitive development. In addition, the teacher used strategic and tactical type of questions which involved negotiation of meaning, handling of misconceptions and attention to minute and idiosyncratic steps of reasoning. Evidence of the effects of these teaching strategies show in the students' performance where their mathematical achievement had improved because of their participation in the CAME intervention. Also, during the interviews the students had shared their views of the influence of the teacher's teaching strategies in their learning approaches and achievement. This particular finding supports the argument stated by Otunuku et al. (2007) that Tongan students' achievement really can be improved if teachers are educated to change their teaching strategies to enhance the formal operational thinking capacity of their students.

During these CAME strategies of teaching and learning, the students exercised their thinking by reflecting on their actions and thoughts. However, teachers were encouraged not to provide all the answers to students' questions but to facilitate and encourage them to explore together a possible solution for given tasks. This was an opportunity for the students to exercise and share their reasoning skills and it often happened in small groups or pairs to react to each other and to look at the problem in more than one way, using their existing knowledge and gaining some insights. In addition, the students' mathematical misconceptions, unclear mathematics ideas, and partial mathematical generalisations were handled and possibly refined in constructive ways.

Overall, these CAME instructional strategies, when used together in teaching mathematics, had the capacity to accelerate the students' cognitive development as well as to improve their reasoning skills resulting in improvement of their achievement and mathematical understanding. The results, shown in Table 4.3, with regards to the reasoning patterns gains made by the experimental group were substantial. In some way, this implies that students in the experimental group became equipped through the CAME teaching strategies and learning activities with a greater capacity to engage with the mathematics curriculum used in Tongan secondary schools. These results provide similar evidence to those from other studies showing that there are far transfer effects of the CAME program (Shayer & Adhami, 2007). In these other studies, there also were benefits to student performance in other subjects, particularly in science, and the students' performance in the National school examination (at the age of 16 years) after three years of the intervention.

It seems reasonable to conclude that the CAME intervention program with its stress on the development of formal operational thinking and students' construction of understanding through peer collaboration could be a solution for improving students' reasoning ability, learning strategies, and mathematics achievement in secondary schools in Tonga. The findings presented in this study are consistent with similar studies conducted in other countries in the world (Shayer & Adhami, 2007; Aunio et al, 2005; Kerridge, 2010; Mok & Johanson, 2000; Olaoye, 2012). In other words, the CAME program was shown to be effective in improving students' mathematics achievement and levels of cognition.

5.3.2 Research Question 2

What are the Year 8 (Form 2) students' motivation and self-regulation levels as a result of participating in the learning of mathematics in the CAME program?

Research question 2 is concerned with the effects of the CAME program in students' learning motivation and self-regulation during the intervention. The results are reported in section 4.2 of chapter 4. The original aim of the CAME program that originated in England was to improve the thinking ability of the students and to contribute to the teaching of mathematics in the classroom where students are struggling to learn mathematics. The assumption was that an increase in students' thinking ability by using the designed thinking lesson activities (from '*Thinking Maths: Cognitive Acceleration in Mathematics Education*') and the prescribed teaching approaches would result in improving the students' mathematics achievement (Shayer & Adhami, 2007). Likewise, the CAME intervention in Tonga had similar aims and assumptions as the CAME program implemented in England. However, the CAME program in Tonga also included an investigation in the effects of the CAME program on students' learning motivation and self-regulation.

As explained in Chapter 3, the data collected to answer this research question included both quantitative and qualitative data. The quantitative data were examined and compared with the qualitative results as a means of a mixed method triangulation of both the quantitative and qualitative data. The method of how these two types of data were analysed was explained in Section 3.5 of Chapter 3.

The quantitative results from the SALE data (see Section 4.2 of Chapter 4 for more information on the results) revealed that students who participated in the CAME intervention program were found to have somewhat more improvements in terms of learning motivation and self-regulated learning in mathematics than the students from the non-CAME group, ie, comparison group. The independent t-test results to compare the mean scores of each scale of the SALE instrument between these two groups (the results are presented in Table 4.5 and Table 4.6 of Section 4.2) suggested that the CAME program is more effective in enhancing Tongan students' learning, resulting in the students gaining increased self-motivation and self-regulation in learning of mathematics lessons. The paired t-test results to examine the changes between pre-test and post-test scores for the experimental and comparison groups revealed that the pre-

post changes of the SALE results varied between these two groups. According to the results, the students who participated in the CAME program had more favourable pre-post changes for all the four scales of the SALE instrument (see Table 4.7 of Section 4.2 for the results). In contrast, the comparison group showed no statistical differences in their pre-post comparisons (see Table 4.8 of Section 4.2 for the results). Effect sizes of the four scales were considerably larger for the experimental group (effect sizes: Learning Goal Orientation = 0.47, Task Value = 0.66, Self-efficacy = 0.58, and Self-regulation = 0.70) than for the comparison group. Combining these two t-tests results indicated that the CAME program had raised the learning motivational and self-regulation levels of students who participated in the CAME intervention in Tonga. Furthermore, as assumed in this CAME program, improving students' cognitive ability may positively influence the students' learning motivation and self-regulation (Adhami & Shayer, 2007; Shayer & Adhami, 2007). The results (see Section 4.1 and Section 4.2 of Chapter 4) are in line with this assumption which has shown that those students who participated in the CAME program had an improvement in their cognitive ability as well as the level of their learning motivation and self-regulation. Furthermore, this result is parallel to the study conducted by Zimmerman (2000a) where he argued that the aspects of learning motivation and self-regulation are related to students' cognitive ability. These two aspects enable the students to transform their cognitive abilities into academic skills and knowledge. In fact, this part of the results provided evidence that there was a positive relationship between developing students' cognitive ability and raising the students' level of learning motivation and self-regulation.

There were some evidences from students' interviews and classroom observations that students in the experimental schools perceived more teacher support and students were involved in more activity tasks than was the case with the comparison school's students (results are explained in Section 4.2.2 of Chapter 4). Students in the experimental group who reflected on their participation in the CAME program intervention revealed that they might have become more self-regulated learners and had increased confidence that they could do better in mathematics although it was seen as a difficult subject to learn. Students in the experimental group were more confident working with challenging activities, were better listeners, and more capable of internalizing the concepts articulated in lessons. The interviews showed the

importance of teacher's behaviour in the classroom. Students sometimes can learn mathematics (or any subject) if they like the teacher's behaviour regardless whether or not they are strong in mathematics. On the other hand, if the teacher does not interact well with the students in the classroom in the learning process, this reduces the students learning motivation and self-regulation in mathematics.

Looking at these results, it can be argued that an improvement in students' motivation towards learning mathematics could also mean that the intrinsic motivation value (Adhami, 2007; Mega et al., 2014; Sutherland, 1992; Pekrun, 1992) of learning mathematics is better appreciated with the CAME program in approaching mathematics tasks, because students are encouraged to think more actively and critically. The gain of this self-intrinsic motivation as described by Zimmerman (2000a) and Adhami (2007) initiated the Tongan students' self-regulated learning. This means that the students in the experimental group engaged in their learning consistently and directed their effort in their learning process in seeking the required knowledge. These two positive attitudes adapted by the experimental students showed that they were more than willing to put in effort to achieve good grades in their mathematics class.

In contrast, students in the comparison group did not have those experiences in learning mathematics in their classroom. According to students' interview responses, they value and understand the critical of mathematics in their lives but they struggled to understand the concepts due to not understanding the teacher's teaching pedagogy and the lesson activities with which they were presented in class. It was very clear from these students' responses that their passion for learning mathematics was slowly reducing and the notion of motivation and regulation to learn this subject was waning.

However, the findings from the students' interviews and the SALE instrument for these two groups had an apparent effect on the students' performance in the NRT2 post-test. Students in the experimental group performed better in the post-test NRT2 than did the comparison group; also the experimental group students had improved in their learning motivation and self-regulation during the intervention while the comparison group found no improvement on these two learning aspects. These findings seem to suggest positive associations between learning motivation, self-regulated learning (shown in Table 4.5, Table 4.6, Table 4.7, and Table 4.8 of Section

4.2) and academic achievement (shown in Table 4.1 and Table 4.2 of Section 4.1). Compared to the students from the comparison group, the experimental group students had lower pre-test scores in the NTR1 and SALE pre-test as shown in Table 4.1, Table 4.2, and Table 4.5 of Chapter 4, but after the CAME intervention, they showed significant improvement in their mathematics achievement in the NRT2 post-test (see Table 4.1) as well as their learning motivation and self-regulation in the SALE post-test (see Table 4.6 and Table 4.7 in Section 4.2). In addition, the findings suggest that the influence of cognitive development on academic achievement may be related to the interplay of self-regulation and motivation on the students' learning. As assumed in this CAME program, improving the students' cognitive development mediated the effects of motivation and self-regulated learning on students' mathematics academic achievement. This finding is consistent with the studies conducted by Mega et al. (2014), Velayutham et al. (2011), Wolters (1999), and Zimmerman and Schunk (2001), who argued that motivational beliefs and self-regulation-based learning have a significant positive relationship with the academic performance, particularly on achievement.

The emphasis on the CAME program can motivate educators to research possible ways to help struggling mathematics students to be more involved in their mathematics class and have more confidence in their ability to succeed in mathematics. The finding of this study suggests that students' motivation toward mathematics and learning regulation can be enhanced through the use of the CAME program that provides support for the students at risk of failure. Also, the results indicate that students' learning regulation had shifted from other-regulation to self-regulation as they learned mathematics through the CAME program. Thus, we suggest that the better use of the CAME program in the Tongan context would be to be part of a practice which allows its own evolution in the learning process whereby good previous instructional teaching in mathematics can be integrated with teaching strategies suggested by the CAME program. The quantitative and qualitative findings described in this section and in Chapter 4 provided support for the efficiency of the CAME program in terms of students' learning motivation and self-regulation in the schools in Tonga.

5.3.3 Research Question 3

What are the teachers' perceptions of their participation in the CAME intervention program?

For answering this research question about teachers' perceptions, the results were reported in Section 4.3 of Chapter 4. The data collected for this research question accumulated from teachers' interviews (one-on-one) and classroom observations. The analyses of the qualitative data painted a picture of teachers' feelings and perceptions toward their participation in the CAME intervention as well as their mathematical teaching experiences. Based on the analyses of the teachers' interviews shown in Section 4.3 of Chapter 4, three main themes encapsulated the findings of this research question: teaching pedagogical transition, students' learning transformation, and suitability for the learning needs of the students.

Teaching pedagogical transition

Teachers in the experimental group felt that their teaching pedagogy has been positively affected by their participation in the CAME program intervention. Their questioning techniques had improved; teachers shared how they were involved in the negotiation of meaning of students' responses, handling their misconceptions, and paying attention to small and distinctive steps of reasoning at the time of each group or class discussion. These teachers put their effort in helping the students to develop their mathematics conceptual understanding and critical thinking instead of guiding them through procedural or rote learning. It was observed and also mentioned by most experimental teachers in their interview that most times in the classroom they tried to scaffold the problem-solving process by not leading the students into procedural and rote learning methods. The teachers provided a series of probing questions to guide the students' thinking and enable them to construct the new knowledge for themselves. Through these processes, students' self-confidence, motivation, and self-regulation toward the mathematics subject naturally increased with greater understanding. In fact, the teachers realized that their primary responsibility as the teacher is to assist the students in analysing their responses and providing background information and then building their thinking skills (Treagust, Duit, & Fraser, 1996). Adhami (2001) described this pedagogy as a strategic and tactical questioning teaching strategy, where

the teacher guides students by a strategic question couched particularly from students' responses.

Most teachers in the experimental schools taught two subjects or two mathematics class levels; they were encouraged during the CAME professional development to establish connections between the agenda of the CAME lessons and the contexts of their ordinary mathematics lessons or other teaching subjects using the same reasoning patterns. They were also encouraged to adopt the teaching skills that they were using in the CAME activities into their teaching approaches in the other mathematics lessons. The results from teachers' interviews and classroom observations in the experimental schools' classrooms revealed that teachers had extended these skills to the teaching of other mathematics lessons or subjects. According to these teachers, the students in their other teaching subjects or mathematics class levels that were not involved in the CAME program found it easier to understand the lesson demonstration and classroom tasks when the teacher practiced the CAME teaching pedagogies during the lessons delivery.

However, it was not easy for the experimental group of teachers to adjust their teaching strategies to what was prescribed by the CAME program. It was difficult for this group of teachers because throughout their teaching career they had practiced traditional teaching strategies as the instructional medium in their classrooms. Basically, the teachers commonly practiced the teaching approaches that focussed on rote learning and procedural knowledge for the students. In many cases, the teachers' teaching practice had followed the examination-based teaching approach where they teach only the parts of the syllabus or mathematical contents that they think will be included and assessed in their common tests or examinations. In fact, the introduction of the formulated CAME teaching pedagogies and the involvement of the five theoretical principles within their teaching strategies (see Section 2.5 of Chapter 2 for more information on the five theoretical principles) was observed to be a difficult transformation process for the majority of the teachers. Some teachers took a couple of weeks to have clear concepts of the CAME teaching approach. However, the PD sessions, regular peer-coaching visits, and teacher's conferences with the researcher had provided assistance and support in terms of the teaching skills and lesson demonstration. Despite these difficulties, the teachers' overview of their participation

in the CAME intervention had a positive influence especially in terms of their teaching skills, students' learning, and using of appropriate languages and leading questions in guiding students' ideas. Section 4.3 of Chapter 4 has more information about these teachers' participation in the CAME program.

In summary, all the participant teachers in the experimental group viewed effective mathematics teaching to be about the act of facilitation and motivation of students' learning and the ability to enhance students' understanding and thinking skills. At the end of this CAME intervention, the teachers knew their role as a classroom facilitator who listened attentively to students' discussions, discerned their learning needs and knew exactly when to step in or out of the discussions, when to provide more scaffolding to enhance understanding, and when to shift the discussion to the next idea. In addition, they were being less didactic and more able to sit back and give the students time to think and answer questions.

Students' learning transformation

A change in students' learning style had been identified by the teachers in the experimental schools. The students were more open for discussion and more committed to what they were told to do in their group or individually. The findings from teachers' interviews showed that the strategy of allowing students to engage in group work while doing problem-solving activities could reduce poor attitudes to mathematics, and provide motivation and peer support which leads to promoting higher achievement. The CAME program encouraged teachers for this teaching approach as a capacity to foster metacognition which has emerged not only as a critical component of effective problem-solving but also as a means of personal empowerment. Furthermore, based on teachers' responses as shown in Section 4.3 of Chapter 4, it is clear that the CAME program also transformed the classroom atmosphere into a more student-centred environment, relative to the traditional mathematics classroom, through its teaching approaches and designed lessons activities.

The classroom environments of secondary schools in Tonga are rigid and structured predominantly with the Tongan culture. In the Tongan culture, children (or adults) are not encouraged to hold discussions or seek questions from parents, church ministers,

or community chiefs when they make a decision in the family, church or community. Such an act by them is considered as lack of respect for these people who hold positions of authority. Consequently, students adopt the same approach in their classroom with the majority of students being afraid to hold a discussion or seek clarification from the teacher in regards to the lessons as they consider this to be an act of disrespect to the authority of the teacher in the classroom (Helu, 1999). However, the implementation of the CAME program required students to discuss and pose questions to the teachers, answer the teacher's questions, and to share their group work findings with the rest of the class rather than with only the teacher. These strategies were quite new to the students but as they became engaged and learned through them, they realized that learning is about social interaction among their peers and the teacher. Therefore, it is reasonable to argue that the CAME intervention in this study provided the Tongan Form 2 mathematics teachers in the experimental group with specific teaching strategies such as appropriate question skills for social construction and metacognition, that could be used within CAME lessons or the regular mathematics lessons to stimulate the students' cognition and enhance their learning strategies in class. This is consistent with Vygotskian notions of ZPD that high quality interactions with the teacher and peers is a better way for development of new knowledge and new learning behaviours occurs. A few interview examples and evidence results on students' performance are presented in Section 4.1 and 4.2 of Chapter 4.

Another finding that emerged from the results of this study was the teachers' reactions to the idea of not marking or grading the students' work when they worked on the CAME lesson activities or their regular curriculum activities. As described in Section 4.4 of Chapter 4, the teachers in the experimental group shared their experiences how this strategy influenced the learning approaches of the students when they knew that their work would not be marked. Yet, grading the students' work in class, such as classroom activity, homework, group work activity, and class attendance was a traditional strategy practiced by most mathematics teachers in these two groups. In fact, the teachers knew that students are very concerned about their class grading, therefore, they practiced this method in their classes for not only as students' formative or summative assessments but also as to encourage the students to study mathematics in school or at home, attend the class regularly, and participate and be involved in the class discussion or group working. However, as the experimental group's teachers

practiced the CAME lesson activities with their students, they realized that students actively engaged in group and class discussion when they know that their work would not be marked. According to these teachers, the students were freer to share their ideas with their peers or the teacher because they knew if they made mistakes it will not affect their class grade marks but it will be corrected for learning. Also, the experimental group teachers recognized that when they informed the students that the activity would not be graded they noticed the more capable students in groups took time to share their ideas with other group members. Similarly, their less able students became involved in their group discussion probably because they knew if they made a mistake it will not make them fail in class but it will be corrected by their peers. Also, most of experimental teachers commented that competition among students did not appear in students' group discussion. In fact, the students did engage and help each other in finding the solutions for their problem-solving activities. Furthermore, the students seem to feel safe amongst their peers and gain some sort of motivation and regulation to share their ideas within the group. More importantly, the sharing of ideas with peers in the group created a fun learning environment where students were seen to enjoy learning mathematics. It was observed in the experimental schools' classrooms that students had identified that solving the mathematical problem activities as a group is the best and most effective learning strategy for themselves. Actually this idea was recognized when the CAME program was designed. The findings are discussed in Section 4.3 of Chapter 4 as the evidence that this aim had been achieved for the three schools that participated in the CAME intervention.

On the other hand, the comparison group teachers did not experience these changes in their teaching as well as in the learning of their students. As reported in Section 4.3 of Chapter 4, it was observed that these teachers had suffered in trying to engage the students in their learning. Therefore it is important for this study to address few reasons that probably caused this issue and possible ways to address them. Firstly, the comparison school teachers require to participate in some professional development training similar to the CAME professional development program where they can improve their mathematics teaching strategies and questioning skills. This is important because the comparison group students mentioned this issue in the interview which imply that the current teaching strategies that practiced by these group of teachers need to be refine. Secondly, apart from teachers' lack of effective teaching strategies, the

lesson activities that regularly used in classrooms for students' learning need to be redesigned. To sustain learning engagement of the students, however, the activities must be "structured to allow more than one puzzling-out route towards some worthwhile insights, providing also that some of these routes are accessible to most of the students. In other words, the activity should be structured to have a 'low floor', 'high ceiling' and a number of routes and steps in between" (Adhami, 2007, p. 35).

Suitability for the learning needs of the students

As presented in Section 4.3 of Chapter 4, teachers in the experimental group agreed that the CAME lesson materials are suitable for their students' learning and their thinking ability, especially for students who were regarded as having learning difficulties in mathematics. According to these teachers, the CAME lesson activities and their prescribed teaching pedagogies had provided a classroom learning culture where the students felt confident to openly express their ideas with their peers. In addition, teachers had mentioned that most students found the lesson activities to be challenging but because they included real-life contexts and how they were structured motivated the students to engage in learning them. This finding is consistent with the results of the study conducted by Wolters and Rosenthal (2000) where they claimed that students who were convinced that their learning activity is relevant, interesting, and useful were more inclined to expend greater effort and persist longer towards completing the activity.

Among these experimental teachers there seemed to be agreement that the CAME lesson materials are suitable for the majority of the Tongan students. However, some teachers felt that the mathematically able students, particularly in the government secondary schools, would find these lesson materials less challenging especially in the first episode of the activities. As mentioned in Chapter 1 and in Chapter 3, the intake of the government secondary schools every year are the top students in the primary school Secondary School Entrance Examination (SSEE). So the majority of these students understand the basic mathematical concepts demonstrated in the first episode of the CAME activities. In fact, the CAME program was designed to help those students who lack that level of understanding in such a way that they can retrieve more quickly those skills and conceptual understanding. For that reason, the first episode was designed not to be so challenging for these type of students but to raise their

attention and allow them to gain some confidence to engage and learn the tasks. Nevertheless, teachers in the experimental schools acknowledged the positive effects of the group-work teaching strategy. Prior to the CAME intervention, the majority of these teachers did not agree to this teaching strategy being used in every lesson in the class. They thought that too much practice of this strategy in their classrooms could allow the students to cheat when doing their work and this may invite chaos in their classroom. However, they had witnessed the benefit of practicing the group-work strategy with peer-tutoring in the learning of their students, especially in their mix-ability classroom. After the professional development, they felt that peer-tutoring is a valuable element of this CAME teaching instruction.

In the view of these teachers, the CAME teaching program with its support materials such as the professional development (PD) workshops was important because it helped develop their teaching skills in mathematics. The PD enabled the teachers to reflect on and discuss some teaching issues that they encountered and the new strategies to address these problems. In concluding, the findings of this CAME program intervention had contributed to improved teaching of mathematics in these three Tongan schools. The CAME program offers scope for these participating teachers to build up a new learning culture where enquiry, collaborative learning and sharing of ideas become dominant themes of their teaching. In this case, mathematics is no longer seen as an individual activity where students were only trained with formal rules or procedures but instead they gained conceptual understanding (Adhami & Shayer, 2007).

5.4 Implication of the study

The findings of this study showed that the CAME intervention, equipped with a rich pedagogy and high-quality lesson activities, did impact on the CAME students' levels of understanding and cognition as measured by the Numeracy Reasoning Tasks (NRTs) instruments. Moreover, this study also investigated the effects of the CAME program on the aspects of learning motivation and self-regulation. Apart from academic achievement, the significant gains in learning motivation and self-regulation of the students supported the fact that knowledge is best constructed by the students themselves through learning collaboratively and sharing (Vygotsky, 1978). Throughout this CAME intervention, the teachers were encouraged to allow enough

time for students in their discussion so they can construct or reflect on their ideas with their peers rather than always rely on the teacher for the answer.

With regards to the teaching pedagogy, the findings from teachers' interviews and classroom observations (see Section 4.3 of Chapter 4 for more information) indicate that the teachers' quality questioning skills tailored with well-designed lesson activities contributed in stimulating social construction and meta-cognition during students' problem-solving activities as well as in stimulating the students' thinking skills. The teachers' teaching practices became more student-centred as demonstrated in the way they communicated, interacted with and allowed students to participate freely and take charge of their learning. The teachers became more effective facilitators in enhancing the students learning. In fact, the students noticed the change in their teachers' teaching strategies and they talked about mathematics classes as engaging, meaningful and fun.

Most importantly, the findings from this study revealed that teaching higher order thinking is appropriate and possible for these Tongan students no matter what levels of thinking ability they have. This study with its findings provided evidence that regardless of students' thinking ability baseline as shown in Table 4.2 of Chapter 4, by using a suitable teaching pedagogy and well-designed lesson activities that link to students' interest and needs, there is a possibility that students will engage, learn and benefit from the lessons, even the higher order thinking lessons. The findings of this study would appear to support Bruner's (1968) argument that "any idea or problem of knowledge can be presented in a form simple enough so that any particular learner can understand it in a recognizable form" (p. 44). However, it is an obligation of the teachers to make sure that the facilities and materials for the lessons activities are available for learning to occur. There may be other factors that link activities to students' interest and needs but that issue is for future research.

Lastly, the series of teachers' professional development sessions that contributed to the students' success is worthy of implementing throughout Tonga. Teachers participated in these PD workshops not only to carefully learn the aspects of the CAME program but also to learn some questioning techniques, such as asking open-ended, probing, questions and asking the students to explain their answers. The structures of the PD described in Section 3.3.2 of Chapter 3 seem to be an effective method for

updating and training the Tongan mathematics teachers in a way that they can become more constructivist and effective facilitators in enhancing students' learning.

5.5 Limitations and biases of the study

For almost all research studies, there are some biases and limitations during the process of investigation. Similarly with this study, there are some biases and limitations which necessarily need to be addressed with regards to the implementation of the CAME program in Tonga.

School context differences

This study is limited in that it was conducted in only three secondary schools in the main island of Tonga. Although the students in these three schools have similar levels of thinking ability to the majority of students in other schools in Tonga, the school's contexts such as teacher's experience, school's facilities, and availability of support varies in most schools. Also, the government secondary schools have more support in terms of facilities, qualified teachers and have an intake of high performance students from the primary school class 6 SSEE. So it may not be possible to generalize the findings to the rest of schools in other islands of Tonga. However, the importance of this study is that it provides an insight into a particular case and this idea may be transferable to other schools in Tonga that have similar contexts.

Researcher participation

Another possible limitation of this study is that the researcher conducted the interview with the students as well as with the teachers. It is acknowledged that allowing the researcher to conduct these interviews may have affected the students' and teachers' responses.

Another limitation is that the analyses of the qualitative data may have been subject to biases because the researcher conducted the analyses and interpretation of the qualitative data with the help of his colleagues and supervisors. Nevertheless, the interview protocol and scripting of the questions were used in an attempt to minimize the effects of researcher bias on the interviews and the subsequent analysis. However, despite its rigor and the depth of the interpretation of the interview data, it can never

be free from the researcher's personal interpretation and biases when analysing the data.

Duration of the intervention

The final limitation of this study is about the duration of the CAME intervention in Tonga which was only eight months for this CAME intervention. Other research studies in the CAME program shown in the literature have been carried out in two years and the investigators were able to complete the 30 CAME lessons before they collected the final data. So the shortened time for the CAME intervention resulted in not completing the full 30 CAME lessons.

5.6 Future Research Direction

In every research study completed, there is always room for further research that grows from it. Several issues arose from this study which are recommended for further investigation. Firstly, the results of this study confirmed the positive effects of the CAME program in terms of academic achievement and learning motivation and self-regulation of the Tongan students. However, questions have risen in regards to how the CAME lessons curriculum can be integrated in the current Tonga Form 2 and Form 3 Mathematics curricula and to provide some insight how this might be accomplished to have the same results as this study. In fact, most secondary school in Tonga are church affiliated schools with similar contexts to the three experimental schools in this study. Therefore, the strategies and implementation method that were practiced in this study can seem to be possible practice in these schools and produce similar results. However, this issue needs further research.

Secondly, while these results demonstrated that the CAME intervention program helped improve the students' mathematical thinking levels, it remains to be seen whether the cognitive gains made by this cohort of students will be translated into improved academic performance in their later schools years of schooling and in the national examinations. According to the results of past CAME research studies, there were evidence that students who participated in the CAME program performed better than their cohort peers in the National Examinations three years after the implementation. So this issue can be investigated in Tonga if the participating schools and students allow the researchers to follow-up the progression of the participating

students in their performances on the Tonga School Certificate examination when they are 16 years old and in the Tonga Senior Secondary School Certificate examination when they are 17 years old. However this is a viable subject for further research.

Lastly, this research study revealed some concerns about the teaching pedagogy of mathematics teachers in many secondary schools in Tonga. These concerns suggested an urgent need for research in regards to the nature of professional development (PD) training conducted in schools, and the teaching programs for pre-teachers administered by the Teacher Institute of Education (TIOE) in Tonga. Although the Ministry of Education and Training in Tonga is seeking a teaching model that can address this issue, the findings of this study suggest that the CAME program with its model of teaching and professional development is a viable option for use to enhance the teachers' teaching skills and students' learning in mathematics classes. Despite these results and suggestions, this issue needs further research.

5.7 Summary

In conclusion, this final chapter of this thesis discussed the findings to answer the three research questions of this study. The implications and limitations of this study were also addressed. Suggestions for future research involving the CAME program in the contexts of Tonga were also considered.

References

- Adams, W. K., & Wieman, C. E. (2011). Development and validation of instruments to measure learning of expert-like thinking. *International Journal of Science Education*, 33(9), 1289 – 1312.
- Adey, P. (1988). Cognitive acceleration: Review and prospects. *International Journal of Science Education*, 10(2), 121-134.
- Adey, P. (2005). Issues arising from the long-term evaluation of cognitive acceleration programs. *Research in Science Education*, 35(1), 3-22.
- Adey, P. (1999). *The science of thinking, and science for thinking: A description of cognitive acceleration through science Education (CASE) (Innodata Monographs 2)*. Geneva: International Bureau of Education.
- Adey, P., Hewitt, G., Hewitt, J., & Laudau, N. (2004). *The professional development of teachers: Practice and theory*. Boston: Kluwer Academic Publisher.
- Adey, P., Robertson, A., & Venville, G. (2002). Effects of a cognitive acceleration programme on Year I pupils. *British Journal of Educational Psychology*, 72(1), 1-25.
- Adey, P., & Shayer, M. (1990). Accelerating the development of formal thinking in middle and high school students. *Journal of Research in Science Teaching*, 27(3), 267 – 285.
- Adey, P., & Shayer, M. (1993). An exploration of long-term far-transfer effects following an extended intervention program in the high school science curriculum. *Cognition and Instruction*, 11(1), 1-29.
- Adey, P., & Shayer, M. (1994). *Really raising standards: Cognitive intervention and academic achievement*. London: Routledge.
- Adey, P., & Shayer, M. (2002). *Learning intelligence: Cognitive acceleration across the curriculum from 5 to 15 years*. Buckingham: Open University Press.
- Adey, P., Shayer, M., & Yates, C. (1989). *Thinking Science: The curriculum materials of the CASE project* (1st edn.). London: Nelson.

- Adey, P., Shayer, M., & Yates, C. (2001). *Thinking science: The curriculum materials of the CASE project* (3rd ed.). London: Nelson.
- Adhami, M. (2001). Responsive questioning in a mixed-ability group. *Support for Learning*, 16(1), 28 – 34.
- Adhami, M. (2007). Cognitive and social perspectives on surprise. *Mathematics Teaching*, 200(1), 34-36.
- Adhami, M., & Shayer, M. (2007). *Thinking maths: Cognitive acceleration in mathematics education*: Oxford: Heinemann Educational Books.
- Ahmed, W., van der Werf, G., Kuyper, H., & Minnaert, A. (2013). Emotions, self-regulated learning, and achievement in mathematics: A growth curve analysis. *Journal of Educational Psychology*, 105(1), 150-161.
- Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology*, 84(3), 261.
- Attard, C. (2011). The influence of teachers on student engagement with mathematics during the middle years. *Mathematics: Traditions and new practices*, 1, 68 – 74.
- Aunio, P., Hautamäki, J., & Van Luit, J. E. H. (2005). Mathematical thinking intervention programmes for preschool children with normal and low number sense. *European Journal of Special Needs Education*, 20(2), 131-146.
- Ausubel, D. P. (1968). *Educational psychology : A cognitive view*. New York: New York : Holt, Rinehart and Winston.
- Backwell, J. L., & Hamaker, T. (2003). *Cognitive acceleration through technology Education (CATE)*. Taunton: Nigel Blagg Associates.
- Baddeley, A. (1990). *Human memory: Theory and practice*. London: Lawrence Erlbaum.
- Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.
- Bandura, A. (1986). *Social foundations of thought and action : a social cognitive theory* Englewood Cliffs, N.J.: Prentice-Hall.

- Barak, M., & Dori, Y. J. (2009). Enhancing higher order thinking skills among inservice science teachers via embedded assessment. *Journal of Science Teacher Education, 20*(5), 459-474.
- Berger, J.-L., & Karabenick, S. A. (2011). Motivation and students' use of learning strategies: Evidence of unidirectional effects in mathematics classrooms. *Learning and Instruction, 21*(3), 416-428.
- Boekaerts, M., Pintrich, P. R., & Zeidner, M. (2000). *Handbook of self-regulation*. San Diego, CA: Academic.
- Breen, S., Cleary, J., & O'Shea, A. (2009). *Constructing and validating an instrument to measure students' attitudes and beliefs about learning mathematics*. Paper presented at the Proceedings of the Third National Conference on Research in Mathematics Education, Dublin.
- Bruner, J. (1978). The child's conception of language. In S. R. J. Jarvella & W. J. M. Levelt (Eds.), *The role of dialogue in language acquisition* (pp. 214-256). NY: Max-Plank-Institut für Psycholinguistik.
- Bruner, J. S. (1968). *Toward a theory of instruction*. New York : Norton.
- Burns, R. B. (2000). *Introduction to research methods* (4th ed). Australia: Addison Wesley Longman.
- Castleberry, A. (2014). NVivo 10 [software program]. Version 10. QSR International 2012. *American Journal of Pharmaceutical Education, 78*, 1 – 2.
- Cervone, D., & Pervin, L. A. (2010). *Personality: theory and research* (11th ed.). Hoboken, NJ: Wiley.
- Chatzistamatiou, M., Dermitzaki, I., Efklides, A., & Leondari, A. (2015). Motivational and affective determinants of self-regulatory strategy use in elementary school mathematics. *Educational Psychology, 35*(7), 835-850.
- Chi, M. T. H., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*(2), 121-152.
- Chow, T. C., & Treagust, D. F. (2013). An intervention study using cognitive conflict to foster conceptual change. *Journal of Science and Mathematics Education in Southeast Asia, 36*(1), 44-64.

- Cleary, T. J., & Chen, P. P. (2009). Self-regulation, motivation, and math achievement in middle school: Variations across grade level and math context. *Journal of School Psychology, 47*, 291-314.
- Cohen, J. (1988). *Statistical power analysis for the behavioural sciences*. (2 ed.). Hillsdale, NJ: Erlbaum.
- Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education* (7th ed.). New York: Routledge Falmer.
- Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design and analysis issues for field settings*. Boston: Houghton Mifflin.
- Creswell, J. W. (2012). *Education research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson.
- Creswell, J. W., & Clark, V. (2008). *Designing and conducting mixed methods research*. Thousand Oaks: Sage Publication.
- Daniels, H. (2005). *An introduction to Vygotsky* (2nd ed.). London: Routledge.
- Demetriou, A., Efklides, A., & Gustafsson, J. (1992). *Training, cognitive change, and individual differences: Neo-Piagetian theories of cognitive development*. New York: Routledge.
- Ding, H., Sun, H., & Chen, A. (2013). Impact of expectancy-value and situational interest motivation specificity on physical education outcomes. *Journal of Teaching in Physical Education, 32*, 253-269.
- Duckworth, E. (1996). *The having of wonderful ideas and other essays on teaching and learning*: New York: Teachers College Press.
- Duit, R., & Treagust, D. (1998). Learning in science – From behaviourism towards social constructivism and beyond. In B. Fraser & K. G. Tobin (Eds.), *International Handbook of Science Education*. Hingham, USA: Kluwer Academic.
- Dullard, H., & Oliver, M. (2012). ‘I can feel it making my brain bigger’: Thinking science Australia. *Teaching Science, 58*(2), 7 – 11.
- Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological review, 95*(2), 256.

- Eccles, J., & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents' achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin*, 21, 215-225.
- Ellis, R., & Barkhuizen, G. (2005). *Analysing learner language*. Oxford: Oxford University Press.
- Endler, L. C., & Bond, T. G. (2008). Changing science outcomes: Cognitive acceleration in a US setting. *Research in Science Education*, 38(2), 149-166.
- Fasi, U. M. L. (1999). *Bilingualism and learning mathematics in English as a second language in Tonga*. Unpublished PhD Thesis. University of Reading, England.
- Finau, T., Treagust, D. F., Won, M., & Chandrasegaran, A. L. (2016). Effects of mathematics cognitive acceleration program on student achievement and motivation. *International Journal of Science and Mathematics Education*, 1-20.
- Feuerstein, R., Rand, Y., & Hoffman, M. B. (1980). *Instrumental enrichment: An intervention program for cognitive modifiability*. (Baltimore, MD: University Park Press).
- Frith, C. D. (2012). The role of metacognition in human social interactions. *Philosophical Transactions of the Royal Society, B: Biological Sciences*, 367(1599), 2213-2223.
- Garton, A. (2004). *Exploring cognitive development : The child as problem solver*. Malden, MA : Blackwell Pub.
- Gibbs, G. (2002). *Qualitative data analysis: Exploration with NVivo*. Buckingham, UK: Open University.
- Goswami, U. C. (2011). *The Wiley-Blackwell handbook of childhood cognitive development / edited by Usha Goswami* (2nd ed.. ed.). Chichester Malden, MA: Wiley-Blackwell.
- Goulding, M. (2002). Cognitive acceleration in mathematics education: teachers' views. *Evaluation and Research in Education*, 16(2), 104 – 119.
- Guerrero, M. C. M. D., & Villamil, O. S. (2000). Activating the ZPD: Mutual scaffolding in L2 peer revision. *The Modern Language Journal*, 84, 51-68.

- Hautamäki, J., Kuusela, J., & Wikstrom, J. (2002). *CASE and CAME in Finland: 'The second wave'*. Paper presented at the 10th International Conference on Thinking, Harrogate.
- Helu, I. F. (1999). *Critical essays: Cultural perspectives from the south seas*. Canberra: Australian National University.
- Hong, A. W. C. (2010). Applying cognitive conceptual approach in developing year 6 pupils' problem solving skills in mathematics. *Pertanika Journal of Social Science and Humanities*, 18, 15-35.
- Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence: An essay on the construction of formal operational structures*. London: Routledge and Kegan Paul.
- Iqbal, H. M., & Shayer, M. (2000). Accelerating the development of formal thinking in Pakistan secondary school students: Achievement effects and professional development issues. *Journal of Research in Science Teaching*, 37(3), 259-274.
- Isoda, M., & Katagiri, S. (2012). *Mathematical Thinking : How to Develop It in the Classroom*. Singapore: World Scientific Publishing Company. Retrieved from
- Jones, M., & Gott, R. (1998). Cognitive acceleration through science education: alternative perspectives. *International Journal of Science Education*, 20(7), 755-768.
- Kaplan, A., & Maehr, M. L. (2007). The contributions and prospects of goal orientation theory. *Educational Psychology Review*, 19(2), 141-184.
- Kerridge, S. (2010). *A study into the improvement in the mathematical Academic Attainment of Low Attainers in Year 7 (11-12 year olds) when Accelerated Learning is used as a teaching pedagogy in the classroom*. Unpublished PhD Theses. Durham University, UK.
- Kim, J. (2005). The effects of a constructivist teaching approach on student academic achievement, self-concept, and learning strategies. *Asia Pacific Education Review*, 6(1), 7-19.
- Koloto, A. H. (1995). *Estimation in Tongan schools*. Unpublished PhD Thesis. University of Waikato, New Zealand.

- Lee, C. Y. (2015). Changes in self-efficacy and task value in online learning. *Distance Education*, 36(1), 59-79.
- Leo, E. L., & Galloway, D. (1996). Conceptual links between cognitive acceleration through science education and motivational style: A critique of Adey and Shayer. *International journal of science education*, 18(1), 35-49.
- Leutwyler, B. (2009). Metacognition learning strategies: Differential development patterns in high school. *Metacognition and Learning*, 4, 111-123.
- Lin, C., Hu, W., Adey, P., & Shen, J. (2003). The influence of CASE on scientific creativity. *Research in Science Education*, 33(2), 143-162.
- Lu, H. L. (2010). Research on peer coaching in preservice teacher education: A review of literature. *Teaching and Teacher Education: An International Journal of Research and Studies*, 26(4), 748-753.
- Manu, S. (2005). *Mathematical understanding and Tongan bilingual students' language switching: Is there a relationship?* Unpublished PhD Thesis. University of British Columbia, Canada.
- Maume, K., & Matthews, P. (2000). A study of cognitive accelerated learning in science. *Irish Educational Studies*, 19(1), 95-106.
- Marcou, A., & Philippou, G. (2005). *Motivational beliefs, self-regulated learning and mathematical problem-solving*. Paper presented at the International group for psychology of mathematics education, Melbourne: PME.
- Mbano, N. (2003). The effects of a cognitive acceleration intervention programme on the performance of secondary school pupils in Malawi. *International journal of science education*, 25(1), 71-87.
- McCann, E. J., & Garcia, T. (1999). Maintaining motivation and regulating emotion: measuring individual differences in academic volitional strategies. *Learning and Individual Differences*, 11(3), 259-279.
- McGregor, D., & Gunter, B. (2001). Changing pedagogy of secondary science teachers: the impact of a two-years professional development programme. *An International Journal of Teachers' Professional Development*, 5(1), 59 – 74.

- McLellan, R. (2006). The impact of motivational “world-view” on engagement in a cognitive acceleration programme. *International journal of science education*, 28(7), 781-819.
- McLellan, R., & Adey, P. (1999). *Motivational style, commitment, and cognitive acceleration: Is it only good schools which opt into successful projects?* Paper presented at the American Educational Research Association, Montreal, Canada.
- Mega, C., Ronconi, L., & De Beni, R. (2014). What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. *Journal of Educational Psychology*, 106(1), 121-131.
- Midgley, C., Kaplan, A., & Middleton, M. (2001). Performance-approach goals: Good for what, for whom, under what circumstances, and at what cost? *Journal of Educational Psychology*, 93(1), 77-86.
- Ministry of Education and Training, T. (2014). *Report of the Ministry of Education and Training for 2013. Tonga*. Government Printing Press, Nukualofa, Tonga: Ministry of Education and Training, Tonga.
- Mok, I., & Johnson, D. (2000). Reasoning algebraically with IT: A cognitive perspective. *Mathematics Education Research Journal*, 12(3), 286-302.
- Multon, K. D., Brown, S. D., & Lent, R. W. (1991). Relation of self-efficacy beliefs to academic outcomes: Meta-analytic investigation. *Journal of Counseling Psychology*, 18, 30-38.
- Newman, D., Griffin, P., & Cole, M. (1989). *The construction zone: working for cognitive change in school.*: Cambridge University Press.
- Niculescuc, B., & Cosma, M. (2013). Specific aspects of military student motivation for their proficient training. *Buletin Stiintific*, 18, 44-51.
- Ní Riordáin, M., Paolucci, C., & O’Dwyer, L. M. (2017). An examination of the professional development needs of out-of-field mathematics teachers. *Teaching and Teacher Education*, 64, 162 – 174.
- Nunnally, J. C. (1978). *Psychometric Theory* (2nd ed.). New York: McGraw-hill.

- Olaoye, A. A. (2012). Cognitive acceleration in mathematics education lesson (CAMEL) in Nigeria. *British Journal of Humanities and Social Sciences (BJHSS)*, 3(2), 77-86.
- Oliver, M., & Venville, G. (2017). Bringing CASE in from the cold: The teaching and learning of thinking. *Research Science Education*, 47, 49-66.
- Oliver, M., Venville, G., & Adey, P. (2012). Effects of a cognitive acceleration programme in a low socioeconomic high school in regional Australia. *International Journal of Science Education*, 34(9), 1393-1410.
- Otunuku, M., Brown, G., & Airini, G. (2013). Tongan secondary students' conceptions of schooling in New Zealand relative to their academic achievement. *Asia Pacific Education Review*, 14(3), 345 – 357.
- Otunuku, M., & Brown, G. T. L. (2007). Tongan students' attitudes towards their subjects in New Zealand relative to their academic achievement. *Asia Pacific Education Review*, 8(1), 117 – 128.
- Pajares, F., & Kranzler, J. (1995). Self-efficacy beliefs and general mental ability in mathematical problem-solving. *Contemporary Educational Psychology*, 20, 426-443.
- Pallant, J. F. (2013). *SPSS survival manual: a step by step guide to data analysis using IBM SPSS* (5th ed.). N.S.W: Allen & Unwin Crows Nest.
- Pekrun, R. (1992). The impact of emotions on learning and achievement: Towards a theory of cognitive/Motivational Mediators. *Applied Psychology*, 41(4), 359-376.
- Perkin, D. N., & Saloman, G. (1989). Are cognitive skills context bound? *Educational Researcher*, 18(1), 16-25.
- Piaget, J., & Inhelder, B. (1967). *The child's conception of space*. New York: W. W. Norton.
- Pintrich, P. R. (2000). The role of goal orientation in self-regulated learning. . In M. Boekaerts, P. R. Pintrich & M. Zeider (Eds.), *Handbook of self-regulation* (pp. 451-502). San Diego, CA: Academic press.

- Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of Educational Psychology, 95*(4), 667-686.
- Pintrich, P. R. (2004). A conceptual framework for assessing motivation and self-regulated learning in college students. *Educational Psychology Review, 16*(4), 385-407.
- Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research, 63*(2), 167-199.
- Pintrich, P. R., & Schunk, D. H. (1996). *Motivation in education: Theory, research and applications*. Englewood Cliffs: Prentice Hall.
- Pintrich, P. R., & Zusho, A. (2002). The development of academic self-regulation: The role of cognitive and motivational factors. In A. Wigfield & J. S. Eccles (Eds.), *Development of achievement motivation* (pp. 249 - 284). San Diego, CA: Academic Press.
- Plomin, R. (2012). How intelligence changes with age. *Nature, 482* (7384), 165-166.
- Pohiva, S. (2014). *An outcomes-based assessment reporting approach for enhancement of teaching and learning in the Pacific islands*. Paper presented at the Proceeding of the Vaka Pasifika Education, Tonga.
- Price, A., Oliver, M., & McGrane, J. (2015). What's working memory got to do with it? A case study on teenagers. *Teaching Science, 61* (2), 26 – 32.
- Schunk, D. H., & Ertmer, P. A. (2000). Self-regulation and academic learning: Self-efficacy enhancing interventions. In M. Boekaerts, P. R. Pintrich & M. Zeider (Eds.), *Handbook of self-regulation*, (pp. 631-650). San Diego, CA: Academic Press.
- Shayer, M. (2003). Not just Piaget, not just Vygotsky, and certainly not Vygotsky as an alternative to Piaget. *Learning and Instruction, 13*, 465-485.
- Shayer, M., & Adey, P. (1981). *Towards a science of science teaching: Cognitive development and curriculum demand*: Heinemann Educational Books Oxford.

- Shayer, M., & Adey, P. (2002). *Cognitive acceleration comes of age*. In Shayer, M. & Adey, P. (Eds.), *Learning intelligence: Cognitive acceleration across the curriculum from 5 to 15 years*. Buckingham. Philadelphia: Open University Press.
- Shayer, M., & Adhami, M. (2007). Fostering cognitive development through the context of mathematics: Results of the CAME project. *Educational studies in Mathematics*, 64(3), 265-291.
- Shayer, M., & Adhami, M. (2010). Realizing the cognitive potential of children 5–7 with a mathematics focus: Post-test and long-term effects of a 2-year intervention. *British Journal of Educational Psychology*, 80(3), 363-379.
- Siegler, R. S. (1998). *Children's thinking* (3rd ed.). Upper Saddle River, N.J.: Prentice Hall.
- Sutherland, P. (1992). *Cognitive development today : Piaget and his critics*. London: London : P. Chapman Pub.
- Tatafu, M., Booth, E., & Wilson, M. (2000). Secondary school failure in Tonga: Implications for inservice and preservice teacher development. *Directions: Journal of Educational Studies*, 19(1), 55 – 81.
- Thaman, K. H., Matang, R., Pene, F., Rainey, M. D., & Alcorn, N. (1998). Equity in, and access to, what kind of education? Some issues for consideration in the Pacific islands. *Directions: Journal of Educational Studies*, 20(2), 3 – 21.
- Torff, B. (2003). Developmental changes in teachers' use of higher order thinking and content knowledge. *Journal of Educational Psychology*, 95(3), 563.
- Treagust, D. F., Duit, R., & Fraser, B. J. (1996). Overview: Research on student's preinstructional conceptions – The driving force for improving teaching and learning in science and mathematics. In D. F. Treagust, R. Duit, and B. J. Fraser (Eds.), *Improving teaching and learning in science and mathematics* (pp. 1 – 14). New York: Teachers College Press.
- Uata, T. (2002). *Comparative effectiveness of high schools in Tonga's education system: A production function approach*. Unpublished Master of Art in Economics Thesis, California State University, Fullerton, USA.

- Urdu, T., & Schoenfelder, E. (2006). Classroom effects on student motivation: Goal structures, social relationships, and competence beliefs. *Journal of School Psychology, 44*(5), 331-349.
- Velayutham, S., Aldridge, J., & Fraser, B. (2011). Development and validation of an instrument to measure students' motivation and self-regulation in science learning. *International Journal of Science Education, 33*(15), 2159-2179.
- Venville, G., & Oliver, M. (2015). The impact of a cognitive acceleration programme in science on students in an academically selective high school. *Thinking Skills and Creativity, 15*, 48-60.
- Vivier, E. D. (2013). *Opening schooling programmes for the kingdom of Tonga: Report of a short-term consultancy*. Commonwealth of Learning, Vancouver, Canada.
- Vygotsky, L. S. (1978). *Mind in society* Cambridge, Mass: Harvard University Press.
- Vygotsky, L. S. (1981). Genesis of higher mental functions. . In J. V. Wertsch (Ed.), *The concept of activity in Societal psychology*. New York: Sharpe.
- Vygotsky, L. S. (1986). *Thought and language/ Lev Vygotsky revised and edited by Alex Kozulin*. Cambridge: MIT Press.
- Wagaba, F., Treagust, D. F., Chandrasegaran, A. L., & Won, M. (2016). Using metacognition strategies in teaching to facilitate understanding of light concepts among year 9 students. *Research in science and technological education, 34*(3), 253-272.
- Walker, R. (2010). Motivating science undergraduates: Ideas and interventions. *International Journal of Innovation in Science and Mathematics Education (formerly CAL-laborate International), 18*(1), 1-13.
- White, R. (1988). *Learning science*. Oxford: Blackwell.
- Wolters, C. A. (1999). The relation between high school students' motivational regulation and their use of learning strategies, effort, and classroom performance. *Learning and Individual Differences, 11*(3), 281-299.

- Wolters, C. A. (2004). Advancing achievement goal theory: using goal structures and goal orientations to predict students' motivation, cognition, and achievement. *Journal of Educational Psychology, 96*(2), 236-250.
- Wolters, C. A., & Rosenthal, H. (2000). The relation between students' motivational beliefs and their use of motivational regulation strategies. *International Journal of Educational Research, 33*(7), 801-820.
- Wong, H. K., & Wong, R. T. (2009). *The first days of school: How to be an effective teacher*. Mountain View, CA: Harry K. Wong Publications.
- Zaporozhets, A. V. (2002). The role of L.S. Vygotsky in the development of problems of perception. *Journal of Russian and East European Psychology, 40*(4), 3-17.
- Zhang,, T., Solmon, M. A., & Gu, X. (2012). The role of teachers' supporting in predicting students' motivation and achievement outcomes in physical education. *Journal of Teaching in Physical Education, 31*, 329-343.
- Zimmerman, B. J. (2000a). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich & M. Zeider (Eds.), *Handbook of self-regulation* (pp. 13-39). San Diego, CA: Academic Press.
- Zimmerman, B. J. (2000b). Self-Efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82-91.
- Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice, 41*(2), 64-70.
- Zimmerman, B. J. (2008). Investigating self-regulation and motivation: Historical background, methodological developments, and future prospects. *American Educational Research Journal, 45*(1), 166-183.
- Zimmerman, B. J., & Schunk, D. H. (2001). *Self-regulated learning and academic achievement : theoretical perspectives* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.
- Zimmerman, B. J., & Schunk, D. H. (2012). Motivation: An essential dimension of self-regulated learning *Motivation and Self-regulated learning: Theory, research and applications* (pp. 1-30). New York: Lawrence Erlbaum Associates.

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APPENDICES

Appendix A Example of the CAME lesson activities with the episodes

Lesson Activity: DECONTAMINATION (Direction and Distance)

Overview

Students explore movement on a plane in terms of values for distance and direction for each move. They recognise the need for scale in describing distance on the page. They compare left/right turns to use compass points for giving directions of turn, and then apply their insights to angles and bearing conventions. They decide which method is more convenient in different real-life situations.

Aims

- Explore movement: directions and distance in maps and real life
- Compare relative and absolute directions.

Curriculum links

- Angle measurements, Scale measurements in coordination with directions, bearing convention

EPISODE 1: Left and Right moves

The students give direction to a robot on a sketch map using only the instructions of left/right for right angle (90^0) turns, and a distance. They realise that a map needs a scale and orientation. Given these, they create instructions for a movement and for its inverse.

EPISODE 2: The compass moves

Students handle a different set of rules to give instructions in term of N – E – S – W turns to another robot. They compare this robot with first one, including the circumstances in real life in which each type of instruction might be used. A possible

extension leads to recognising how the move in two dimensions can be added and subtracted.

EPISODE 3: Smooth-turn moves

Students collaboratively compare two robots that can turn through continuous angles rather than at right angles. One is a bearing robot, while the other is a LOGO robot (following the conventions used in LOGO programming where angles are measured from the direction the robot is currently facing).

Appendix B Activity episode as structured into teaching and learning phases

Activity: Decontamination (Direction and distance)

Aims: Explore movement: directions and distance in maps and real life. Also compare relative and absolute direction.

Curriculum links: Angle measurements, scale measurement in coordination with directions, and bearing convention.

EPISODE 1: Left and Right moves (10 – 15mins)

Resources: Worksheet 1, rulers, 1cm squared grid on acetate

Phase 1: Whole class preparation: Story to set up the Left-Right robot context

There is a desert island which developers want to turn into a holiday resort. But there is a problem: two sites of extremely dangerous toxic waste. The developers decide to use a robot to decontaminate the sites carefully. The robot will land on the site and will then need to be directed back to the landing place to refill its spray before heading off to the other toxic waste site.

Ask the class:

If I were the robot, how could you give me directions to move from here to near Sione (use any name in your class) there?

Ideas may include turning to the right direction, distance in steps or metres, forward/backwards, left/right, N-E-S-W. For example: ‘take 4 steps’; ‘turn anti-clockwise’; ‘turn clockwise’; ‘go forwards, backwards, left or right’; ‘go 3 steps’; ‘East’, Perform all students directions literally (including bumping into desks) showing where the instructions have to be precise.

After setting the scene, tell the class that the robot they will be using understands forward, backward, left (which means rotating 90° to the left), right (which means rotating 90° to the right) and a distance (in this case, steps).

Now the students guide the teacher around the room, perhaps from the farthest corner to the door. It is helpful to include a situation where the teacher is amongst the students, and being asked to turn by someone facing them who gets the directions muddled up, since their 'right' is the teacher's 'left'; Discuss how to get the robot to turn 180° (L, L or R, R).

Phase 2: Collaborative Learning: Pair/small group work

Give out a copy of Worksheet 1 (the map of the island) to each pair/group. Explain there are three possible landing sites available (shown on the map as A, B and C), that the toxic waste sites are marked (as 1 and 2) and that on the island there is a big lake that the robot cannot cross.

You could suggest that the robot lands at A, or the class could agree on a landing point, or each group could choose their own landing point.

Tell the class that you are not expecting them to be able to solve the problem yet. Give them two minutes to discuss in groups what problems there are and what information you need from me to overcome them.

Now explain that the robot starts in the middle of the landing place, at an angle of 90° . Make available some rulers and some acetate grids. 1 square on the grid (or 1 cm on a ruler) is 100m on the ground. Demonstrate writing a move with a turn, e.g. Forward 3, Right 2 (no need for writing 'forward' after a turn) with the return journey as Back 2, Right 3. (The robot returns to its original landing place before heading off to the next toxic site, to enable students to discuss 'undoing' a set of actions.)

Students continue to work on guiding their robot in pairs. They can record their instructions on Worksheet 1, next to the map. Some students may orientate themselves so that they are facing the same way as the robot. Others may turn the paper after each move; this could form part of the whole class discussion. It is important that the return journey is worked out so that comparisons between the outward and return journeys can be made.

Phase 3: Whole class Collaborative Learning: Sharing and discussion

Quickly notate the directions for the journey from A to 1 and back again. Ask for comments. Students may have spotted that the return journey has some similarities to the outward journey. The instructions are in reverse order and the turns have been changed. So the movement can be reversed from code alone: to reverse F15, R6 you could write B6, R15 or RR6,L15 or LL6,L15.

Give directions for a possible outward journey from A to 2 and discuss how to work out the return journey.

EPISODE 2: The compass moves (15-20 mins)

Phase 1: Whole class preparation: the four compass directions.

You could ask the class to imagine there is a need to use the robots repeatedly, for checking and decontamination etc, so that there are other kinds of robots.

That was the cheapest robot available. We will call that a Left-Right robot. There is an alternative called an N-E-S-W robot. What can you tell me about this robot?

Possible responses: 'It can move north, south, east or west'; 'It needs to know which way is north before it can start'; 'It always knows where north is'.

The students should be able to explain that the robot will move north or east or south or west a particular distance. They may point out that north was not marked on the map on Worksheet 1. On this particular map N needs to be drawn on a vertical line pointing up the page.

Give out Worksheet 2, one per pair, and ask how it may be useful.

It may be appropriate to clarify which way is east once we know which way north is. In some cases a lively discussion may ensue if you ask the class if they know where north actually is, and how they know it is so. Possible response could involve use of a compass, where the sun rises or is at noon, or local knowledge of a road going south or north. For real-life maps when you have found north you can orientate the map to it, which is a good way of reading a map.

NB it is not possible for this robot to move diagonally, e.g. NE etc

Phase 2: Pair/small group work

Students should work out instruction for new robot, for the same moves they worked on before.

The key question here are:

- What do you do to work out the homeward journey for this robot?
- What are the links between this robot and the first robot?
- Can you turn instructions for a Left-Right robot into instructions for a N-E-S-W robot?
- Which method of giving directions is easier? Why?

Typical responses would be: ‘The N-E-S-W robot is easier to use’; ‘We know where north is so N-E-S-W is easy’; ‘We’re looking down on it, so N-E-S-W is best’; ‘I wouldn’t say “go east the south” to get to the Chinese shop. I’d say “go straight on and then turn right”’; ‘If I’m talking to someone I use left and right’.

Phase 3. Whole class sharing and discussion

- Discuss the links between the two different robots, including the similarities and the differences.
- A discussion of which is the easiest or best method to use should throw up suggestions that favour both versions. This could lead to an understanding that different methods are going to be more or less appropriate in different situations.

Appendix C Numeracy Reasoning Task 1 (NRT1 Pre-test)

PRETEST

Part A: Multiple Choice

Instruction: Read the question carefully and circle the letter in front of the most correct answer. Remember, only one correct answer for each question.

- The number 1712 can be written in words as
 - Ten thousands, seven hundreds and twelve
 - Seventeen thousands and twelve
 - Seventeen hundreds and twelve
 - One thousand and seventy one hundreds and two
- 5691 is greater with how much on 5291?
 - 4
 - 40
 - 400
 - 4000
- $78 \div 3 =$
 - 26
 - 29
 - 39
 - 234

4. Which clock is the same as 21:30?

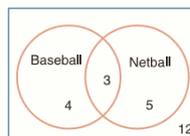


A. B. C. D.

5. 225% is equal to

A. $2 \frac{1}{2}$ B. $2 \frac{1}{4}$ C. $2 \frac{1}{2}$ D. $2 \frac{3}{4}$

6. From the Venn diagram below, how many people play baseball or netball, but not both?

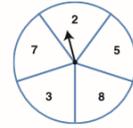


A. 4 B. 5 C. 9 D. 12

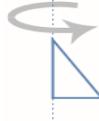
7. Mele's presentation started at 9:25 am, she finished at 10:12 am. How long does she do her presentation?

A. 37 minutes B. 47 minutes C. 42 minutes D. 32 minutes

Use this information to answer question number 8 and 9. The arrow on the spinner is spun again and lands on a number.



8. What is the probability of getting a 8 when spinning?
 A. $\frac{2}{5}$ B. $\frac{3}{5}$ C. $\frac{4}{5}$ D. $\frac{1}{5}$
9. What is the chance that it lands on an even number?
 A. $\frac{1}{5}$ B. $\frac{4}{5}$ C. $\frac{2}{5}$ D. $\frac{3}{5}$
10. Sione's team has six player. They need score 78 points to win a competition. To win the competition, the lowest mean (average) number of points needed per player is
 A. 11 B. 13 C. 12 D. 14
11. A triangle is rotated around the dotted line.

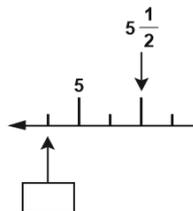


Which three-dimensional shape is formed?



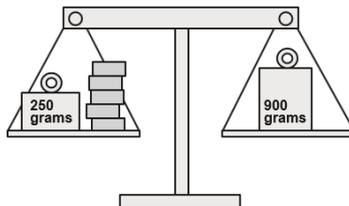
- A. B. C. D.

12. Write the number that goes on the number line inside the box.



- A. 4 B. $4\frac{1}{4}$ C. $4\frac{1}{2}$ D. $4\frac{3}{4}$

13. Pita has 5 blocks that all the same weight. He balances them on the scale (meafua) with 2 weights (mea fkmamafa).



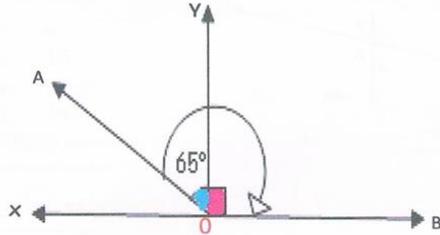
Calculate the weight of 1 block.

- A. 250g B. 260g C. 130g D. 150g

14. When some money was shared out equally between 8 people, each person received \$9.00. If the same amount was shared between 12 people, how much money would each person received?

- A. \$9.00 B. \$6.00 C. \$12.00 D. \$72.00

15. What is the name given to type of the angle \widehat{AOB} in the diagram?



- A. Acute
 B. Obtuse
 C. Right angle
 D. Reflex

Part B: Short Answer

Instruction: Read the questions carefully and write your answer on the spaces provided.

16. Here is a number sequence. Write in the missing number.

3 6 10 15

17. From the year 1990 to 1995, the population of Tofoa village increased by 20% each year. If the population of Tofoa village in 1992 was 15000, what was the population in 1990?

18. My garden centre sells young olive plants at 85 cents each. I have \$30 to spend. How many plants can I buy with the \$30?

Write in the missing numbers to each of Question 19 and Question 20:

19. Expand and Simplify $2(2m - 3k) - m + 8k$

20. Find the value of m if $m = \frac{6k+2n}{4k+3n}$ where $k = 4$ and $n = -2$

Appendix D Numeracy Reasoning Task 2 (NRT2 Post-test)

POSTTEST

PART A: MULTIPLE CHOICE

Instruction: Read the questions carefully and circle the letter in front of the most correct answer.

1. The number written in the box below is:

Nine hundreds and thirteen thousands, five hundreds and fourteen

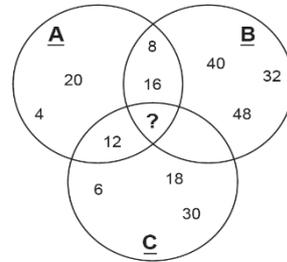
- A. 903 354
- B. 9 135 014
- C. 913 514
- D. 9 013 514

2. In the Venn diagram all the numbers in Set A are multiples of 4.

In Set B the numbers are multiples of 8 and Set C contains multiples of 6.

Which number should go in the intersecting segment of all three sets?

- A. 14
- B. 24
- C. 36
- D. 28



3. What is the simplest form of this algebraic expression?

$$5(2x - y) + 4y - 2x$$

- A. $10x + 9y$
- B. $8x - y$
- C. $10x - y$
- D. $8x + y$

4. Form 2 students of Vava'u High School went by bus for a field trip. The school paid \$120 for the bus, and 15% of the cost for waiting time during the trip.

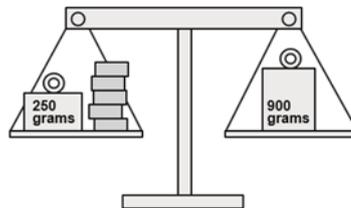
What is the total cost for this bus field trip?

- A. \$102
- B. \$128
- C. \$138
- D. \$18

5. Pita has 5 blocks that all the same weight. He balances them on the scale (meafua) with 2 weights (mea fakamamafa).

Calculate the weight of 1 block.

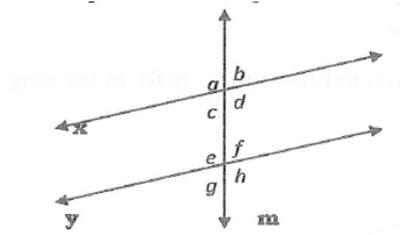
- A. 250g
- B. 260g
- C. 130g
- D. 150g



6. In the diagram below, line x is parallel to line y and line m is a transversal.

Which angles are alternate angles?

- A. c and b
- B. c and e
- C. c and f
- D. c and g



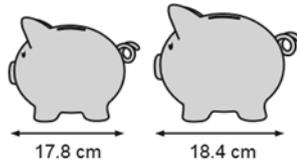
7. Which of these has the greatest value?

- A. $\frac{3}{4}$
- B. $\frac{4}{10}$
- C. 50%
- D. 0.3

8. What is the probability of getting a 6 from rolling a six sides dice once?

- A. $\frac{4}{6}$
- B. $\frac{3}{6}$
- C. $\frac{2}{6}$
- D. $\frac{1}{6}$

9. The picture shows the length of two money boxes.



What is the difference between the two lengths?

- A. 0.6cm
- B. 1.6cm
- C. 2.6cm
- D. 1.2cm

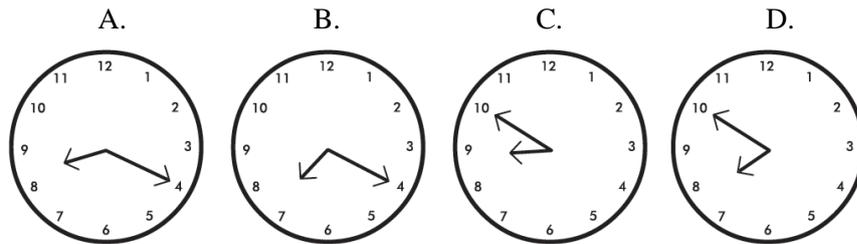
10. How long would Sione's flight if it takes off at 11:15pm and land at 5:45am the next day?

- A. 5 hours and 30 minutes.
- B. 5 hours and 45 minutes.
- C. 6 hours and 30 minutes.
- D. 6 hours and 45 minutes.

11. The bus arrives at the bus stop at 8:10 am.

Ana looks at the clock and says, "I must leave in 20 minutes."

What time is showing on the clock then Ana leave to the bus stop?



12. A six-sided die is rolled once. What is the probability that the number rolled is an even number?

- A. $\frac{2}{6}$
- B. $\frac{3}{6}$
- C. $\frac{4}{6}$
- D. $\frac{5}{6}$

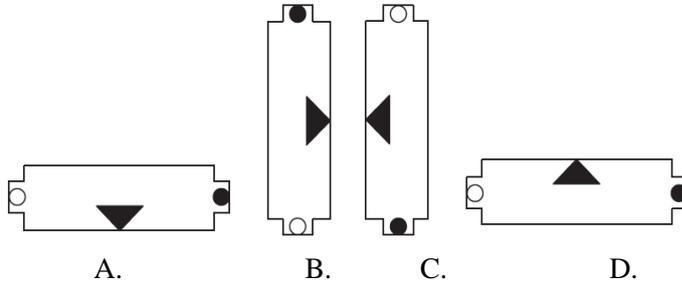
13. Hiko has 5 vanilla beans. Their lengths are: 10 cm, 12 cm, 7 cm, 8 cm and 13 cm. The average length of these vanilla beans is:

- A. 8 cm
- B. 9 cm
- C. 10 cm
- D. 11 cm

14. A shape below has been rotated a quarter turn clockwise



What is the shape look like before it was rotated?



15. When some money was shared out equally between 8 people, each person received \$9.00. If the same amount was shared between 6 people, how much money would each person received?

- A. \$9.00 B. \$8.00 C. \$12.00 D. \$72.00

SECTION B: Short Answer

Instruction: Read each question carefully and write your works and answer on the spaces provide on each question.

16. Write the missing number in the space provided.

$$56 \div \square = 14$$

17. Here is a number sequence. Write in the missing number.

3 6 10 15

18. Find the value of P if $P = \frac{-2x+7y}{3y-3x}$ where $x = -3$ and $y = 2$

19. Ana had \$20 to spend. She bought a pencil case at \$3.75 and 4 metres of rope, at \$1.50 per metre and half kg sugar at \$2.10 per kg. How much did she spend?

20. From the year 1990 to 1995, the population of Taanea village decreased by 10% each year. If the population of Taanea village in 1992 was 15000, what was the population in 1990?

Appendix E The adapted SALE instrument (English version)

Students' Adaptive Learning Engagement in Mathematics

Name: _____

School: _____

Date: _____

Gender: Male or Female

Age: _____

Direction for Students

Here are some statements about you as a student in this class. Please read each statement carefully. Circle the number that best describes what you think about these statements.

There are no 'right' or 'wrong' answers. Your opinion is what is wanted.

For each statement, draw a circle around

- 1 if you *Strongly disagree* with the statement
- 2 if you *Disagree* with the statement
- 3 if you are *Not sure* about the statement
- 4 if you *Agree* with the statement
- 5 if you *Strongly agree* with the statement

Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

Learning Goal Orientation	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
<i>In this mathematics class ...</i>					
1. One of my goals is to learn as much as I can.	1	2	3	4	5
2. One of my goals is to learn new maths contents.	1	2	3	4	5
3. One of my goals is to master new maths content that is taught.	1	2	3	4	5
4. It is important that I understand my work.	1	2	3	4	5
5. It is important for me to learn the maths contents that are taught.	1	2	3	4	5
6. It is important to me that I improve my mathematics skills.	1	2	3	4	5
7. It is important that I understand what is being taught to me.	1	2	3	4	5
8. Understanding maths ideas is important to me.	1	2	3	4	5
Task Value	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
<i>In this mathematics class ...</i>					

9. What I learn can be used in my daily life.	1	2	3	4	5
10. What I learn is interesting.	1	2	3	4	5
11. What I learn is useful for me to know.	1	2	3	4	5
12. What I learn is helpful to me.	1	2	3	4	5
13. What I learn is relevant to me.	1	2	3	4	5
14. What I learn is of practical value.	1	2	3	4	5
15. What I learn satisfies my interest.	1	2	3	4	5
16. What I learn encourages me to think.	1	2	3	4	5
Self-efficacy	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
<i>In this mathematics class ...</i>					
17. I can master the skills that are taught.	1	2	3	4	5
18. I can figure out how to do difficult work.	1	2	3	4	5
19. Even if the mathematics work is hard, I can learn it	1	2	3	4	5
20. I can complete difficult work if I try.	1	2	3	4	5
21. I will receive good grades.	1	2	3	4	5
22. I can learn the work we do.	1	2	3	4	5
23. I can understand the contents taught.	1	2	3	4	5
24. I am good at mathematics subject.	1	2	3	4	5
Self-regulation	Strongly disagree	Disagree	Not sure	Agree	Strongly agree
<i>In this mathematics class ...</i>					
25. Even when tasks are uninteresting, I keep working.	1	2	3	4	5
26. I work hard even if I do not like what I am doing.	1	2	3	4	5
27. I continue working even if there are better things to do.	1	2	3	4	5
28. I concentrate so that I will not miss important points.	1	2	3	4	5
29. I finish my work and assignments on time.	1	2	3	4	5
30. I do not give up even when the work is difficult.	1	2	3	4	5
31. I concentrate in class.	1	2	3	4	5
32. I keep working until I finish what I am supposed to do.	1	2	3	4	5

Appendix F The SALE instrument in Tongan language

Ko e Tu'unga Feliliuaki e Tokanga e Tamasi'i Akó Ki he Fiká

Hingoa: _____

'Apiakó:

'Aho: _____

Tangata pe Fefine:

Ta'u motu'á:

Fakahinohino ki he Fānau akó:

Ko ha fanga ki'i fakamatala 'eni fekau'aki moe koe 'i ho' o hoko ko e fānau ako he kalasi ni. Lau fakalelei e fakamatala takitaha. Siakale'i e mata'ifika 'okú ne fakamatala'i lelei taha e anga ho' o fakakaukau ki he ngaahi fakamatalá ni.

'Oku 'ikai ha me'a ia ko e tali 'tonu' pe 'hala.' Ko e me'a 'oku fie ma'ú ko ho' o fakakaukau. 'I he fo'i fakamatala kotoa pē, hanga 'o siakale'i 'a e fika

1. kapau 'okú ke *Ta'efiemālie* 'aupito ki he fakamatalá.
2. kapau 'okú ke *Ta'efiemālie* ki he fakamatalá
3. kapau 'oku 'Ikai ke ke fakapapau' i e fakamatalá
4. kapau 'okú ke *Fiemālie* ki he fakamatalá
5. kapau 'okú ke *Fiemālie* 'aupito ki he fakamatalá

Fakapapau' i 'okú ke tali e fehu' i kotoa pē. Kapau 'e liliu ho' o fakakaukau ki ha tali, hanga pē 'o tamate'i ia ka ke siakale'i ha fika kehe. 'Oku 'i ai ha ngaahi fakamatala he 'ū fehu'í, 'oku meimei tatau pē ia mo ha ngaahi fakamatala kehe. 'Oua te ke tokanga ki ai. 'Omi pē 'e koe ho' o fakakaukau ki he ngaahi fakamatalá kotoa.

Fakataukei 'o e Taumu'a Akó	Ta'efie mālie 'aupito ki ai	Ta'efie mālie ki ai	'Ikai fakapa pau'i	Fiemālie ki ai	Fiemālie 'aupito ki ai
<i>'I he kalasi fiká ni ...</i>					
1. Ko e taha 'eku ngaahi taumu'á ke u ako e lahi taha te u ala lavá.	1	2	3	4	5
2. Ko e taha 'eku ngaahi taumu'á ke u ako lahi ange ki he kanoloto 'o e fiká.	1	2	3	4	5
3. Ko e taha 'eku ngaahi taumu'á ke u taukei 'i he ngaahi kanoloto fo'ou 'o e fiká 'oku ako'í.	1	2	3	4	5
4. 'Oku mahu'inga ke mahino kiate au 'eku ngāué.	1	2	3	4	5
5. 'Oku mahu'inga kiate au ke u ako e ngaahi kanoloto 'o e fiká 'oku ako'í.	1	2	3	4	5

6. 'Oku mahu'inga kiate au ke toe fakalalakaka ange 'eku ngaahi taukei fakafiká.	1	2	3	4	5
7. 'Oku mahu'inga ke mahino kiate au 'a e me'a 'oku ako'i 'aki aú.	1	2	3	4	5
8. 'Oku mahu'inga ke mahino kiate au e ngaahi fakakaukau fakafiká.	1	2	3	4	5

Fakamahu'inga'i e Ngāue	Ta'efie mālie 'aupito ki ai	Ta'efie mālie ki ai	'Ikai fakapa pau'i	Fiemālie ki ai	Fiemālie 'aupito ki ai
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The kalasi fiká ni ...

9. 'E lava ke faka'aonga'i e me'a 'oku ou akó 'i he'eku mo'ui faka'ahó.	1	2	3	4	5
10. 'Oku mālie 'a e me'a 'oku ou akó.	1	2	3	4	5
11. 'Oku 'aonga ke u 'ilo'i e me'a 'oku ou ako ki aí.	1	2	3	4	5
12. 'Oku tokoni kiate au e me'a 'oku ou akó.	1	2	3	4	5
13. 'Oku 'aonga kiate au e me'a 'oku ou akó.	1	2	3	4	5
14. 'Oku mahu'inga 'aupito e me'a 'oku akó ke u faka'aonga'i.	1	2	3	4	5
15. 'Oku fakafiemālie'i pē 'eku tokangá he me'a 'oku ou akó.	1	2	3	4	5
16. 'Oku fakatupu fakakaukau e me'a 'oku ou akó.	1	2	3	4	5

Ko 'eku Malava ke Fakatupu ha Olá	Ta'efie mālie 'aupito ki ai	Ta'efie mālie ki ai	'Ikai fakapa pau'i	Fiemālie ki ai	Fiemālie 'aupito ki ai
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The kalasi fiká ni ...

17. Te u lava 'o taukei he ngaahi pōto'i 'oku ako'í.	1	2	3	4	5
18. Te u lava 'o fakakaukau'i e founga hono fai e ngāue faingata'á.	1	2	3	4	5
19. Te u lava 'o ako mei he fiká neongo 'ene mamafá	1	2	3	4	5
20. Te u lava 'o fakakakato ha ngāue faingata'a kapau te u feinga.	1	2	3	4	5

21. Te u lava 'o mā'u ha maaka 'oku lelei.	1	2	3	4	5
22. Te u lava 'o ako e ngāue 'oku mau faí.	1	2	3	4	5
23. 'E lava ke mahino kiate au e kakano 'o e me'a 'oku ako'í.	1	2	3	4	5
24. 'Oku ou sai he lēsoni fiká.	1	2	3	4	5
Ko 'Eku Tu'unga Malava 'Iate Au peé	Ta'efie mālie 'aupito ki ai	Ta'efie mālie ki ai	'Ikai fakapa pau'i	Fiemālie ki ai	Fiemālie 'aupito ki ai
<i>'I he kalasi fiká ni ...</i>					
25. Neongo e ta'eoli e me'a ke faí, ka 'oku ou kei ngāue pē.	1	2	3	4	5
26. 'Oku ou ngāue mālohi neongo kapau 'oku 'ikai ke u sai'ia he me'a 'oku ou faí.	1	2	3	4	5
27. 'Oku hokohoko atu pē 'eku ngāué neongo kapau 'oku 'i ai ha me'a lelei ange ke faí.	1	2	3	4	5
28. 'Oku ou tokanga kakato ke 'oua na'á ku ta'e mā'u ha ngaahi me'a mahu'inga.	1	2	3	4	5
29. 'Oku ou fakakakato 'eku ngāué mo 'eku 'asainimeni he taimi totonu.	1	2	3	4	5
30. 'Oku 'ikai ke u fo'i neongo 'oku faingata'a e ngāué.	1	2	3	4	5
31. 'Oku ou tokanga 'i he kalasí.	1	2	3	4	5
32. 'Oku hokohoko atu pē 'eku ngāué kae 'oua kuo 'osi e me'a ne totonu ke u faí.	1	2	3	4	5

Appendix G Students' semi-structured interviews questions

- 1 Do you like study mathematics? Why?
- 2 Can you share your view and your experiences about your learning mathematics in your class this year? You may include any difficulties, enjoyment or suggestion.
- 3 In learning mathematics, do you like working in a group or working individually when doing problem-solving? Explain why?
- 4 Throughout this year, can you scale your level of learning motivation and self-regulation in mathematics as '1' is very low and '5' improves or high? Explain why you selected that number?
- 5 Please share your experiences about your learning mathematics under the CAME program compare to what you have experienced in learning mathematics in Form 1?
- 6 Can you share your experience on how does the CAME program have impacts on your learning achievement?
- 7 What about the learning motivation and self-regulation? Can you elaborate how does the CAME program had impacts on these two learning aspects?
- 8 Please share any difficulties or problems that you faced with of using the CAME program in your learning mathematics this year?
- 9 Which part of the CAME program that you like the most? Which parts that you do not like?
- 10 When you get stuck on any given mathematics problem or activity, what did you do? Can you explain why you do that?
- 11 Do you think that CAME program should be part of the teaching curriculum of your school in mathematics? Why?

- 12 Let's talk about pre and post-test. Can you explain how does your performances on those two tests was?
- 13 Is there anything else that you need to share that I have not included in our interview?

Appendix H Teachers' semi-structured interviews questions

- 1 How many years of your being a Form 2 Mathematics teacher?
- 2 What were the most challenging things that you experienced in teaching Form 2 Mathematics students this year? Explain why?
- 3 How would you describe what needs to do to improve the students' learning mathematics in this school?
- 4 Please share how you like or dislike using the CAME program in your class? If it is possible, explain why?
- 5 From your experience, how do the structures of the CAME program supported your teaching practices?
- 6 Can you explain some positive or negative aspects of the CAME program that you experienced when you practised that with your students in the classroom?
- 7 Can you share how did your students respond to the CAME lesson that you recently did in class?
- 8 Please share, what are the distinctive features of the CAME lessons compared to non-CAME lessons that you have experienced so far?
- 9 Please share your views on how does the suitability of the CAME materials suit your mixed-ability classroom?
- 10 What is your view regarding the transferability of the CAME teaching approaches as you used in teaching your students?
- 11 How does the CAME program had an impact on the students' achievement, learning motivation, and self-regulation?
- 12 CAME expected performance gains in TSC, TSSC, and TNFC examinations. Would you expect this to happen? If so, for which students in particular?

13 Is there anything else that you need to share that I have not included in our interview?

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