TONGAN STUDENTS' ACHIEVEMENT AND MOTIVATION FOLLOWING A MATHEMATICS COGNITIVE ACCELERATION PROGRAM

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This paper presents the implementation and evaluation of a Cognitive Acceleration in Mathematics Education (CAME) program in a sample of Tongan secondary schools in regards to students' achievements, motivation and self-regulation. The program materials were adapted to the Tongan educational context and participating teachers were supported for eight months. This study employed a mixed-methods and quasi-experimental design with 219 Year 8 students as the experimental group and 119 Year 8 students as the comparison group. There were statistically significant differences in the mean scores between the pre-test and post-test of both achievement and learning engagement instruments with the CAME students, but not with the comparison students who studied the same mathematics content with their regular Tongan program. These results indicate that learning mathematics under the CAME program had a positive effect on levels of students' mathematics achievement, motivation and self-regulation. Students also reported changes to the ways they learned mathematics.

Keywords: Mathematics, Self-regulation, Motivation

SITUATING THE STUDY IN TONGAN SCHOOL EDUCATION

In recent decades, there has been a growing concern over the low level of 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. Students tend to do well on questions that require simple recall of information but have difficulties in answering questions that demand understanding and application of 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; Uata, 2002), a shortage of qualified teachers to teach mathematics (Tatafu, Booth, & Wilson, 2000), students' low socioeconomic circumstances (Uata, 2002), an examination system that reinforces rote learning, and the mismatch between students' cognitive ability and cognitive demands of the mathematics curricula (Pohiva, 2014). As 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.

The instructional approach known as 'Cognitive Acceleration in Mathematics Education (CAME)' (Adhami & Shayer, 2007; Shayer & Adhami, 2010) was adapted to the Tongan school system, implemented and evaluated to address the need of Tongan mathematics education, and this instructional approach is the focus of this research. Based on the theories of Piaget and Vygotsky, the CAME teaching approach entails five working principles known as 'pillars' of cognitive acceleration in each lesson, namely concrete preparation, cognitive conflict, construction, metacognition and bridging. Even though cognitive aspects are important, motivation and self-regulation also play an important role in students' learning. Many studies on motivational beliefs have suggested that there is a positive relationship between self-regulation, motivational beliefs and academic performance. Pekrun (1992) argued that lack of proper consideration of students' motivational beliefs and self-regulation when engaged in academic tasks will profoundly impact upon their cognitive strategies of learning and hence their academic achievement.

The purpose of this study was to investigate the effect on Year 8 (Form 2) mathematics students of implementing the CAME program in a sample of secondary schools in Tonga. The effects of the CAME program were determined by examining the differences in students' responses to three instruments that evaluated students' content knowledge ((NRT1, NRT2) and students' motivation and self-regulation (SALE). This study was guided by two research questions:

1. To what extent does the CAME program change Tongan Year 8 students' academic achievement in mathematics? and
2. What are the Year 8 students' motivation and self-regulation levels as a result of participating in the learning of mathematics in the CAME program?

RESEARCH METHODS

Research design: This research used a quasi-experimental design with multiple data sets (Cohen, Manion, & Morrison, 2011) that was conducted in four secondary schools in Tongatapu, the main island of Tonga. The study utilised both quantitative and qualitative data including pre- and post-tests, interviews, and classroom observations. Using a mixed-methods sequential explanatory design (Creswell & Clark, 2008), this study integrated the strengths of quantitative and qualitative data. Participating teachers were provided with a professional development program based on the work of Adey, Hewitt, Hewitt, and Laudau (2004).

Participants: The experimental group consisted of 219 Year 8 students and seven teachers from three schools that were involved in the CAME program. The comparison group consisted of 119 Year 8 students and four teachers from a school that was not involved in the CAME program. All four schools were church-affiliated schools with most students from low socioeconomic families in outlying rural villages and farming communities of Tongatapu.

Data source and instruments: Content knowledge was assessed by the Numeracy Reasoning Tasks 1 and 2 (NRT 1 and NRT 2), each with 20 items that were constructed by the first author to ascertain the mathematics content knowledge of the Year 8 students. Students' motivation and self-regulation was measured by Students' Adaptive Learning Engagement (SALE) **(**Velayutham, Aldridge & Fraser, 2011**).** Learning goal orientation, task value, and self-efficacy are three components of motivation while self-regulation is a separate scale. Each scale of the instrument had Cronbach alpha reliability greater than 0.8. The surveys were followed by semi-structured reflective interviews to assess the students' experiences and perspectives on participating in the CAME program but these are not part of this proposal.

RESULTS

Students' Performance on the Numeracy Reasoning Tasks 1 and 2 (NRTs): To address Research Question 1: To what extent does the CAME program change Tongan Year 8 students' academic achievement in mathematics, an independent samples t-test (see Table 1) was conducted. The results showed that there were initially no significant differences between the experimental group and the comparison group for students' performance on the NRT1 pre-test (prior to the CAME intervention). However, there was a statistically significant difference in the post-test with the students in the experimental group scoring a higher mean than the comparison group. In terms of cognitive gains, the students in the experimental schools started at a lower mean cognitive level than their counterparts in the comparison school, but in the post-test they made greater cognitive gains over the intervention period, with an effect size of 2.04. The results suggest that the CAME program was successful in improving students' understanding of these mathematical concepts as well as in advancing the cognitive ability of mathematics students in the experimental groups.

Table 1 Independent samples t-tests of pre-test and post-test for the NRTs (N = 338)

	Experimental group (N=219)		Comparison group (N=119)		t-value	p
	Mean	SD	Mean	SD		
Pre-test (NRT1)	10.24	4.94	11.31	6.56	1.70	0.09
Post-test (NRT2)	22.11	6.57	15.83	5.11	9.04[***]	0.001
Mean gain	11.87		4.52			
Effect size (Cohen's d)	2.04		0.77			

***p < 0.001

Students' Motivation and Self-Regulation Levels: To address Research Question 2: What are the Year 8 students' motivation and self-regulation levels when participating in the learning of mathematics in the

CAME program?, an independent samples t-test was conducted. The results showed statistically significant differences between the pre-test and post-test mean scores of the four scales of the SALE instrument for students in the experimental group (see Table 2) suggesting that the CAME program was effective in improving the students' motivation and self-regulation levels. In contrast, there were no statistically significant differences between the pre- and post-test scores among students in the comparison group. (Not shown due to space limitations)

Table 2 SALE pre-test and post-test comparison for students in the CAME program (N=219)

Scale of SALE	Pre-test		Post-test		t-value	Effect size (Cohen's d)
	Mean	SD	Mean	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	4.42	0.44	7.86***	0.70

***$p < 0.000$

DISCUSSION

Results from the CAME intervention in these experimental schools show positive effects on students' mathematics achievement, motivation and self-regulation compared with students from the comparison school. The findings of this study show that the interventions in the CAME program can make a difference to students' thinking skills and cognitive capacity, leading to their improved academic achievement as well as improved self- regulation and motivation.

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