

# Raising the quality of primary level mathematics teaching and learning in schools in American Samoa: A model for South Africa

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*Against the background of concerns around teaching and learning outcomes in primary school mathematics in South Africa, this article presents two studies conducted in American Samoa and seeks to draw implications for the teaching and learning of mathematics in South Africa. American Samoa has a very similar educational context to South Africa. The purpose of the two empirical studies was to evaluate the effectiveness of a mathematics intervention with Grade 3 learners, Connecting Math Concepts Comprehensive Edition Level C (CMCCE) curriculum which is framed by a structured and explicit pedagogy. The findings in the two studies indicate that providing teachers who have limited content knowledge and pedagogical content knowledge with explicit and fully developed instructional plans can have an almost immediate and positive effect on children's mathematics proficiency.*

**Keywords:** mathematics learning; explicit pedagogy; teaching mathematics; American Samoa

## Introduction

In the past three decades, economically unequal countries, including countries in sub-Saharan Africa, have prioritised improving access to education and quality educational outcomes. Many governments highlighted mathematics and science as key areas of knowledge and competence (Reddy, Van der Berg, Van Rensburg & Taylor, 2012). The focus has also been on ensuring that children achieve basic minimum competences of literacy and numeracy so that they are able to benefit from and contribute to society. Although there have been major gains in access to education in sub-Saharan Africa, huge concerns have been voiced over the poor achievement outcomes in mathematics, science and literacy (Akyeampong, Pryor & Ampiah,

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2006; Carnoy, Chisholm & Chilisa, 2012; Fleisch, 2008; Pontefract & Hardman, 2005; UNESCO, 2012; Vavrus, Thomas & Bartlett, 2011). This research has shown that the poor achievement outcomes of children are associated strongly with poor quality of teaching. More specifically, it has been found that quality learning and achievement is hindered by poor content knowledge and poor pedagogical content knowledge of the teachers.

In South Africa, despite massive curriculum reform since 1994, similar trends in poor achievement outcomes have been documented. South African's poor performance in the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) assessments undertaken in fifteen school systems is a serious concern. South African Grade 6 learners underperformed in reading and mathematics when compared to the SACMEQ average in both the 2000 and 2007 assessments (Moloi & Chetty, 2011; Moloi & Strauss, 2005). In 2007, 35% of learners were situated at level 2 – the emergent numeracy level. The results for South Africa's standardised Annual National Assessments (ANA) conducted in 2012 in mathematics are alarming despite a slight increase from 2011. This assessment involved more than 7 million learners. Learner performance in Grade 3 mathematics was recorded at 41%. The Grade 4 result was recorded at 37%; Grade 5 at 30%; Grade 6 at 27% and Grade 9 at 13% (Department of Education, 2012). These are national average percentage marks at the different grades.

Thus, one can gauge that providing educational opportunity to children in economically unequal countries is wrought with many challenges. The dominant model of educational delivery expects that teachers, when provided with a list of objectives or outcomes and a collection of instructional materials, will be able to develop lesson plans that result in successful learning, as the OBE model did in South Africa (Echevarria, Short & Powers, 2006). However, the dearth of content knowledge of indigenous teachers results in very poor teacher-created instructional activities (e.g., Carnoy, Chisholm & Chilisa, 2011; Pacific Regional Advisory Committee [RAC], 2011).

The aim of this article is to present two studies conducted in American Samoa that evaluated the effectiveness of providing fully developed, scripted lesson plans to poorly educated, indigenous teachers of mathematics in American Samoa, and to draw implications for the South African context.

## **Research methodology and design**

### **The research context**

American Samoa is a context very similar to South Africa. The children in American Samoa come to school speaking a language other than English, namely Samoan. The medium of instruction is English. The teachers come from the same educational background as the children they teach, so their educational foundation is very weak. There is no university on the island. Those who go off-island to obtain a college degree

usually do not return to the South Pacific, where the teacher salary is about one-third of that offered on the mainland of America. Consequently, 63% of the teachers on the island have not completed any kind of college degree (Pacific RAC, 2011).

Two quasi-experimental studies with matched comparison groups were conducted to evaluate the effects on Grade 3 mathematics learning when poorly educated, indigenous teachers were taught to deliver a structured mathematics intervention through the use of fully developed, scripted lesson plans.

### **A structured mathematics learning and teaching intervention**

Coyne, Kame'enui and Carnine (2011) and Gersten, Beckman, Clarke, Foegen, Marsh, Star and Witzel (2009) summarise the research on the design of effective lessons in mathematics. Effective mathematics lessons provide explicit, systematic instruction that makes broadly applicable strategies conspicuous and provides adequate practice for students to achieve mastery. Cumulative, distributed review ensures retention. Component skills are taught to mastery and integrated into complex procedural knowledge. Most importantly, lessons are designed to teach the 'big ideas' of a content area. In mathematics, an important big idea for young children is the algebraic thinking involved in understanding and solving word problems, with missing values occurring in any location in the problem structure.

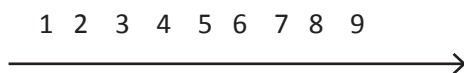
Research has found that instruction on solving word problems that is based on underlying problem structure (or big ideas) leads to statistically significant positive effects on measures of word-problem solving (Xim, Jitendra & Deatline-Buchman, 2005; Darch, Carnine & Gersten, 1989). The Connecting Math Concepts Comprehensive Edition Level C (CMCCE) curriculum (Engelmann, Kelly & Carnine, 2012) for Grades 2 or 3 is designed to teach children explicitly and systematically an algebraic mapping strategy for solving all forms of the three categories of word problems: classification, comparison, and change problems. The mapping strategy is based on an analysis of the underlying structure of these word problem categories.

- Comparison problem: Fred has  $x$  more/less than Wilma. Wilma has  $y$ . Fred has  $z$ .
- Change problem: Dennis had  $x$  eggs. He used  $y$  eggs in his recipe. He has  $z$  eggs left over.
- Classification problem: There were  $x$  trucks and  $y$  cars on the ferry. The total number of vehicles on the ferry was  $z$ .

To solve any of these problems, any two values must be given in order to solve for the third value. Typically, young children are taught that 'get more' means add, and 'lose or get rid of' means subtract. For this keyword strategy to work, the missing value must always be the one that the problem scenario ends up with. Children who learn this keyword strategy have difficulty when they move into algebra, where the missing number may be any of the 3 values. If the value the student is to solve for is the one that the word problem scenario started with, then we must subtract if the scenario

'got more' and must add if the scenario 'got rid of', contrary to what the popular keyword strategy would advise. For example, after Dennis made his cake, he had 8 eggs left. He used 4 eggs in his recipe. How many eggs did he start with? One must add 8 plus 4 to find the number of eggs Dennis had before he used some in his recipe.

The CMCCE algebraic mapping strategy uses a 'number family' analysis as the big idea children learn to use to solve all word problems. The number family strategy derives from the number line that children learn first.



If you start at 4 and go right, you get bigger numbers. On the number line, as in a number family, the big number is also always on the right.

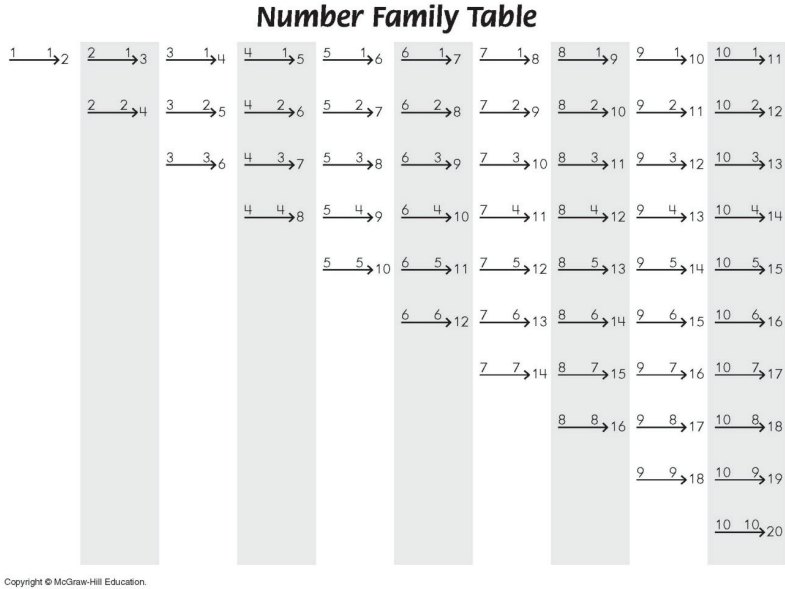
A number family:  $\xrightarrow{4 \quad 6}$  \_\_\_\_

These are the first rules children are taught about number families: The biggest number is always at the end of the arrow. The other two smaller numbers are always on top of the arrow. If the big number is missing, you add the smaller numbers. If a smaller number is missing, you subtract from the big number. For the above number family, children would write:  $4 + 6 = \square$

But for this number family  $\xrightarrow{\quad 7}$  12 the children would write the problem:

$$12 - 7 = \square$$

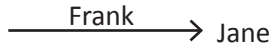
Children learn their initial facts as number families that represent all the basic facts for addition and subtraction (see figure 1). Later, children also learn a similar set of basic facts for multiplication and division. The most immediate value from learning facts as number families is the economy in the amount of material to be learned. Only 55 families express all the basic 220 addition/subtraction facts. The number family strategy for solving addition–subtraction word problems extends beyond the basic fact families to include eventually any set of 3 numbers. As children become facile in using number families, they develop a deep understanding of the commutative property.



**Figure 1. Number family table for learning fact families for addition and subtraction**

**Mapping comparison problems.**

In the fully developed lesson plans of the CMCCE, children learn step by step how to map word problems onto the number family, mastering each component skill before learning the next level of complexity. The first step in the comparison problem strategy is simply to identify the big number in a sentence. For example, ‘Jane has more than Frank’, maps like this:



These sentences use the same map: ‘Jane is taller than Frank’, ‘Jane is smarter than Frank’, ‘Jane is richer than Frank’, ‘Jane built a longer fence than Frank’, ‘Jane eats more samosas than Frank’, and so on. These sentences require the reverse mapping:



‘Jane is shorter than Frank’, ‘Jane scored lower than Frank’, ‘Jane has less money than Frank’, ‘Jane lives in a smaller house than Frank’, ‘Jane eats fewer hamburgers than Frank’ or ‘Jane has fewer pets than Frank’. Translating these sentences, without any numbers, onto a number family map is for many students, especially English language learners, perhaps the most challenging task in correctly mapping a comparison word problem. The teacher provides the children with extensive practice in this component skill until they have mastered it, by reading a script to present one item after the other and to give correction feedback and models until children master the skill.

Mastery of this component skill simplifies mapping later comparison statements with numbers in them. For example, 'Jane has 12 more crayons than Frank has' becomes:

$$\underline{12} \quad F \rightarrow J$$

And 'Jane is 12 inches shorter than Frank' becomes:

$$\underline{12} \quad J \rightarrow F$$

The difference number is the other small number. Once children can map the comparison sentence, moving on to mapping the entire problem and solving it is a cinch, no matter where the missing value is.

1. Jane is 12 inches shorter than Frank. Jane is 60 inches tall. How tall is Frank?

$$\begin{array}{c} 60 \\ \underline{12} \quad J \rightarrow F \end{array}$$

2. Jane is 12 inches shorter than Frank. Frank is 48 inches tall. How tall is Jane?

$$\underline{12} \quad J \rightarrow \overline{48}$$

3. Jane is 48 inches tall. Frank is 60 inches tall. How much taller is Jane than Frank?

$$\begin{array}{c} 48 \quad 60 \\ \text{dif} \quad J \rightarrow \overline{F} \end{array}$$

In problem 3, where the missing number is the difference, children learn to label the difference number 'dif.'

Once a problem is mapped on the number family, the procedure for solving for the missing value is always the same: If the big number is missing, you add. If a small number is missing, you start with the big number and subtract. In problem 1, the big number is missing, so you add. In problems 2 and 3, a small number is missing, so you start with the big number and subtract. The mapping strategy they learn about sentences that compare quantities applies to virtually all statements that express comparative numerical values (e.g., 'The pole is 311 feet shorter than the tower').

### Mapping change problems.

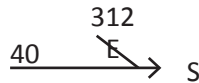
The number family mapping strategy also works with change problems. Here is a change problem: 'Tina had some berries. She gave away 40 berries. She ended up with 312 berries. How many did she start out with?' In mapping change problems, the first component skill children learn is to place either the start (S) or the end (E) number at the end of the arrow, as the big number, depending on whether the problem scenario ends up with more or starts with more. You start with more when

you lose things, so S goes at the end of the arrow. If you get more in the scenario, then you end up with more, so E goes at the end of the arrow.

In the above change problem, Tina gave away berries, so she started with more:



As with the comparison problems, children get a great deal of practice interpreting core statements. These persons either started with more or ended with more: Mark broke eggs; Mark gathered eggs; Jan ate fish; Jan caught fish; Etta picked berries; Etta ate berries; Dan spent money; Dan earned money. When the children are firmly at mastery interpreting the core statement, they map sentences with numbers in them, placing them on the number family arrow. Here is the number family for the Tina's berries problem:



The CMCCE lesson plans include mastery tests every 10 lessons with provisions for re-teaching specific sub-skills if the class did not reach this criterion: 80% of the children must score at least 80% correct to move on in the lesson sequence.

## Study 1

### Subjects

The subjects were 188 Grade 3 children of American Samoa who came from homes and communities where English was rarely spoken. Even their news media provided little experience of English. However, the official language of instruction at school is English. Because the children do not speak English and the teachers are more fluent in their indigenous language, English is not used very much in the lower grades. By Grade 3 the teachers still communicate mostly in Samoan to the children, and translate occasionally into English.

Subjects were selected from only those schools on the Samoan islands that had at least three tracks. American Samoa used a tracking system for creating classes when there was more than one class per grade level. The tracking decision was based on the evaluation of the teacher of the previous grade. The following criteria were used to select tracks for inclusion in the study: If the school had five tracked Grade 3 classes, the lowest two tracks were included, namely tracks 1 and 2. If the school had three Grade 3 classes, only the lowest performing track, track 1, was included. The lowest track in a four-track school and the lowest track in a five-track school were selected to be the experimental groups. The second track in both these schools was included as a control group. Table 1 displays these selection decisions. Five schools were included in Study 1.

The teachers had no college degree, but had been educated in the same island community in which they were now teaching. They were more fluent in Samoan than in English. These characteristics are analogous to South Africa.

**Table 1: Descriptive information regarding subject selection process**

<i>School</i>	<i>No. of Students in Gr. 3</i>	<i>No. of Gr.3 tracks in school</i>	<i>Tracks selected for the study</i>	<i>n</i>	<i>Treatment Group</i>
No. 1	92	4	Track 1	22	Experimental
No. 1	92	4	Track 2	18	Control
No. 2	118	5	Track 1	26	Experimental
No. 2	118	5	Track 2	21	Control
No. 3	72	3	Track 1	20	Control
No. 4	105	5	Track 1 and 2	44	Control
No. 5	101	5	Track 1 and 2	37	Control

## Method

The experimental teachers implemented the CMCCE fully developed lessons. Programme specialists skilled in the implementation of the programme coached and monitored the teachers. The programme specialists provided initial training in the use of the programme materials in after-school practice sessions and through in-class modelling, and observed the teacher once a month to gather implementation fidelity data. The implementation fidelity scores the teachers achieved were either 14 or 15 each time. (A perfect score was 16.)

The teachers in the control groups used the Harcourt Brace Math Advantage Textbook (Harcourt Brace, 1998) and resource materials to teach to the territory mathematics standards for Grade 3. The district provided considerable professional development island-wide using consultants from the Pacific Regional Education Laboratory and local experts. This professional development focused on teaching teachers to develop lesson plans to align with the standards and how to use resource materials in teaching those lessons. The programme also gave considerable focus to developing teacher content knowledge through a daily after-school programme at the local community college. District-level and school-level monitors made monthly classroom visits.

## Measures

The American Samoa Department of Education Standards-Based Assessment (SBA) was used to evaluate Grade 3 mathematics performance island-wide. The SBA is a criterion-referenced test based on American Samoa's academic content standards in math. The test was locally developed with input provided by teachers, administrators, Pacific Regional Education Laboratory consultants, curriculum coordinators, specialists and other ASDOE staff.



The Grade 3 test evaluated 31 standards using one item for each standard. The test required two hours for administration. The district administered the SBAs near the end of the school year (April). Teachers were reassigned to classes to administer the tests, so that no teacher administered the test to her/his own class. Grade 3 is the earliest grade level that sits for the SBA tests in American Samoa, so no pre-test scores were available from end of Grade 2.

## **Results**

Only the tracking system, based on Grade 2 teachers' evaluation of each child's ability and the consequent placement of the child into a track for Grade 3, gave a measure of student knowledge prior to the treatment. In this analysis, we assume the children in the lowest tracks are equivalent in performance across the larger schools that were included in this study. This is a fair assumption, because (a) all the schools had been using the same instructional model, and (b) the island population is so homogeneous. Note that the experimental group represented the lowest 1/4th and the lowest 1/5th of their respective Grade 3 school populations, while the control groups included a larger proportion, 1/3 to 2/5, of their respective Grade 3 school populations. The larger proportion in the sample for the control groups presents a bias in favour of the control schools, because the sample was likely to include initially higher performing students than in the experimental group. This selection bias increases the possibility of a false negative finding and decreases the possibility of a false positive. Given these assumptions, an Analysis of Variance (ANOVA) is an appropriate statistic. To control for Type 1 error with multiple groups, an omnibus test was applied.

To evaluate the end-of-year mathematics performance of the Grade 3 children included in the evaluation, we compared the mean of the total scores on the SBA tests for each group. Table 2 displays the descriptive statistics. An omnibus ANOVA indicated a significant difference in the mean total scores of the groups ( $df=6$ ,  $F=8.77$ ,  $p < .0001$ ). Subsequent post-hoc analyses are presented in table 3. Because the two experimental groups achieved such similar scores, they were combined to simplify the post-hoc analyses.

**Table 2: Descriptive statistics** \*Adequate yearly progress measure

	<i>n</i>	<i>Total school population</i>	<i>Mean AYP*</i>	<i>Mean total score</i>	<i>SD of mean total score</i>
Experimental class school 1	22	92	25%	54.36	8.82
Experimental class school 2	26	118	31%	54.85	17.02
Control class school 1	18	92	14%	38.56	9.71
Control class school 2	21	118	13%	40.95	8.68
Control school 3	20	72	14%	37.40	13.88
Control school 4 (2 classes)	44	105	16%	43.36	10.33
Control school 5 (2 classes)	37	101	15%	42.43	10.47

**Table 3: Post-hoc analyses of the difference in the means between the combined experimental groups and each of the control groups**

	<i>n</i>	<i>AYP</i>	<i>Score</i>	<i>SD</i>	<i>F ratio</i>	<i>p value</i>	<i>Effect size*</i>
Experimental groups	48	28%	54.63	13.74			
Control class school 1	18	14%	38.56	9.71	20.65	< .0001	0.75
Control class school 2	21	13%	40.95	8.68	17.65	< .0001	0.76
Control school 3	20	14%	37.40	13.88	22.07	< .0001	1.22
Control school 4 (2 classes)	4	16%	43.36	10.33	19.49	< .0001	0.91
Control school 5 (2 classes)	37	15%	42.43	10.47	20.14	< .0001	0.92

\*Effect size (Cohen's *d*) equals the difference in the mean of the scores of the experimental and the control group divided by the pooled standard deviation of 12.92.

The post-hoc analyses showed consistent significant large positive differences across all comparisons favouring the combined experimental group. An effect size of .2 is considered small, .5 is medium, and .8 is a large effect (Cohen, 1988). This positive finding is bolstered by the subject selection bias against a positive finding.

## Study 2

In the following school year, we evaluated the same treatment and control group variables in a second study using a new cohort of Grade 3 students and a new measure.

### Measures

We used the Test of Early Primary Mathematics Skills/Common Core Standards (TEPMS, Center for Applied Research in Education, 2012) to evaluate the mathematics abilities of children in Grade 3. The TEPMS subscales are listed below with their respective reliability coefficients (Cronbach's alpha).

1. Solve word problems. (Cronbach's  $\alpha = .68$ )

a. F is 12 more than B.  
B is 77.  
What number is F?

b. P is 22 less than T.  
P is 53.  
What number is T?

c. A bus started out with some people. Then 12 more people got on the bus. 35 people ended up on the bus. How many people did the bus start out with?

d. A truck started out with some boxes on it. Then the driver took 67 boxes off the truck. The truck ended up with 21 boxes on it. How many did the truck start out with?

2. Write multiples of 9 and 4. (Cronbach's  $\alpha = .92$ )

a. 27 36 \_\_\_\_\_

b. 16 20 \_\_\_\_\_

3. Place value: Add hundreds, tens, and ones. (Cronbach's  $\alpha = .83$ )

a.  $10 + 6 =$

d.  $500 + 10 + 2 =$

b.  $300 + 0 + 8 =$

e.  $800 + 40 + 0 =$

c.  $90 + 0 =$

f.  $200 + 0 + 7 =$



4. Count money. (4 items,  $\alpha = .89$ )
5. Multiply 1- and 2-digit numbers. (Cronbach's  $\alpha = .86$ )
6. Add or subtract numbers less than 10. (Cronbach's  $\alpha = .83$ )
7. Add and subtract 2- and 3-digit numbers in columns. (Cronbach's  $\alpha = .89$ )
8. Indicate greater than or less than for 2- and 3-digit numbers. (Cronbach's,  $\alpha = .92$ )

The first subscale measured the ability to solve comparison and change word problems. The remaining seven subscales measured basic mathematics skills.

## Subjects

The children in the experimental group consisted of the lowest performing track of four Grade 3 tracks in one school. The control groups were selected from another school. We selected the lowest track and the middle track of that school as control groups for comparison to the performance of the subjects in the experimental treatment.

All the 82 subjects were again Grade 3 children, who came from homes and communities where Samoan is spoken. The experimental teacher had not completed a college degree; the control teachers had both completed a college degree. All teachers were educated in the same island community in which they were now teaching. They were all more fluent in Samoan than in English, which was limited. The teacher quality bias of a college degree favoured the control group, a false negative, as did the selection bias of initially lower-performing children in the control group.

## Method

The experimental and control treatments were the same as in study 1. Research assistants administered the measures. Teachers were present to help invigilate.

## Results

We first evaluated the overall effect using a Manova statistic on the total score. The difference across the three groups was significant ( $df=2$ ,  $F=57.0$ ,  $p < .0001$ ). Having found a very significant overall effect (effect size = 1.59, 1.79), we proceeded with the post-hoc subscale analyses (see table 4).

**Table 4. Descriptive statistics and results of post-hoc analyses for each subscale**

	<i>n</i>	<i>Mean</i>	<i>SD</i>	<i>Effect size</i>	<i>F value</i>	<i>p value</i>	<i>Pooled SD</i>
Word problems (subscale 1)					33.52	<.0001	1.73
Exp	23	2.74	2.12				
Control 1	28	0.36	1.10	1.38			
Control 2	31	0	0	1.58			
Multiplication facts (subscale 2)					81.86	<.0001	4.42
Exp	23	9.04	2.16				
Control 1	28	1.04	2.76	1.81			
Control 2	31	0.97	2.63	1.83			
Place value (subscale 3)					32.15	<.0001	2.00
Exp	23	5.39	1.23				
Control 1	28	2.61	1.57	1.39			
Control 2	31	2.29	1.62	1.55			
Count money (subscale 4)					23.8	<.0001	1.74
Exp	23	3.39	0.99				
Control 1	28	1.57	1.71	1.05			
Control 2	31	0.77	1.33	1.51			
Multiply 1- and 2-digit numbers (subscale 5)					9.48	<.001	1.46
Exp	23	3.96	0.21				
Control 1	28	2.36	1.66	1.10			
Control 2	31	2.84	1.46	0.77			
Add/Subtract Nos. < 10 (subscale 6)					7.03	<.01	1.94
Exp	23	7.7	0.76				
Control 1	28	5.79	2.44	0.98			
Control 2	31	6.61	1.69	0.56			
Column addition and subtraction (subscale 7)					5.41	<.01	5.45
Exp	23	17.39	3.43				
Control 1	28	12.61	6.06	0.88			
Control 2	31	14.52	5.37	0.53			
Greater than, less than, equals (subscale 8)					4.38	0.016	2.28
Exp	23	5.35	1.43				
Control 1	28	3.75	2.3	0.70			
Control 2	31	3.77	2.51	0.69			

The post-hoc analyses again showed very large and significant differences favouring the experimental group on all subscales, except for subscale 8 (indicating <, >, or =). On subscale 8 the effect sizes of the differences were large (.70, .69), but because of greater variability within groups, the differences only approached statistical significance ( $p = .016$ ).

## Discussion and conclusion

Two studies using two different cohorts of Grade 3 children and two different sets of measures showed that indigenous teachers with limited content and pedagogical knowledge consistently had an immediate and strong positive effect on Grade 3 children's mathematical proficiency. Neither study used random assignment of subjects to treatment, which would have ensured the comparison groups started as statistically equivalent. However, the selection of the classes for the treatment was not random. The classes that used the fully developed lesson plans were selected to do so because the classes were especially unproductive. The skill level of the children was low: in general, many of the children could not count in English or write numbers. In addition, the experimental teachers were especially weak in their content knowledge and English proficiency, such that teaching was very difficult for them and their own school attendance was extremely poor.

As the intervention began, the experimental teachers with poor attendance started coming to school regularly. Two years later, the one teacher who had the poorest attendance, now had nearly perfect attendance. She became keenly interested in her children's progress, eager to obtain test results and, generally, displayed confidence that she did not seem to have before. She loves teaching from a scripted, well-designed programme. And anecdotally, people comment that her English has improved as well as her own knowledge of basic mathematics.

The CMCCE programme used in the present studies is a later edition of the same mathematics programme used in an earlier study in South Africa (Grossen & Kelly, 1992). In that study, rural indigenous Grade 2 (Tsonga-speaking) children taught by indigenous teachers outperformed Grade 2 English-speaking children taught by English-speaking teachers in a private urban school in South Africa, with an effect size greater than 1 standard deviation. The children in that study who learned from the early version of the CMCCE programme completed two years of the highly structured, fully developed sequence of lessons taught by their indigenous teachers. The qualifications of the indigenous South African teachers were similar to those in American Samoa, having no college degree and limited English-speaking ability. They also taught well-behaved children, large classroom groups with limited teaching materials, similar to American Samoa.

Designing a sequence of excellent lessons is an intricate and difficult task. A developing science undergirds the design of better lessons. Here are some highlights of this emerging science as it was used in engineering the CMCCE lessons. They have

important implications for curriculum design in economically unequal countries, including South Africa:

- Lessons should be carefully sequenced, and learning carefully scaffolded. New concepts should be linked to known concepts.
- Analytic skills need to be developed in learners from the early years of mathematics learning (Glick & Sahn, 2010; Lewin, 2009). The use of the number family strategy to teach algebraic thinking is an example of how CMCCE provides a strong foundation in analytic skills.
- Pedagogical content knowledge should not be divorced from content knowledge. In the CMCCE the ability to draw linkages with other elements of mathematics, the explanations and questions teachers use to ensure deep understanding of concepts, all merge pedagogical and content knowledge together, both of which are significantly and positively correlated with student achievement, according to Carnoy et al. (2011).
- Content coverage and its differentiation, appropriate pacing, and higher levels of time on task are all more easily achieved with a carefully prepared plan. Carnoy et al. (2011) highlight the critical importance of these elements.
- Demonstration, modelling, independent practice of new skills, and cumulative review are all planful activities that are carefully laid out for the teacher to follow in CMCCE. Carnoy et al. (2011) found these elements correlated with better achievement.
- Curriculum coherence, cognitive demand of content and pacing, and the adjustment of pace to learner ability are important principles of instructional design. Reeves and Muller (2005), in the context of their study in the Western Cape Province, use these principles to define the concept 'opportunity to learn'.
- Teacher proficiency in the language of instruction is critical to good educational outcomes (Hoadley, 2012; Setati & Adler, 2000; Taylor, 2007; 2008). The CMCCE-provided scripts enable teachers who are only semi-proficient in English to act as very proficient teachers.
- Teacher feedback on student responses and systematic on-going assessment of learning and teaching are also critical elements of 'opportunity to learn' (Hoadley, 2012; Reeves & Miller, 2005; Taylor, 2007; 2008). The CMCCE has built-in mastery checks through 'individual (oral) turns' and 10-lesson written tests of mastery and optional lessons with remedies for problems. Many of the features of effective pedagogy and content knowledge can be built into the curriculum, eliminating the prerequisite that every teacher must be an effective curriculum designer before effective instruction can be delivered to the children in the classrooms.

## Acknowledgement

The author gratefully acknowledges the input and critique of this paper by Dr Bonnie Grossen, Centre for Applied Research in Education (CARE), Hillsboro, Oregon, USA.

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