International Journal of Humanities and Social Science Invention (IJHSSI)
ISSN (Online): 2319 – 7722, ISSN (Print): 2319 – 7714
www.ijhssi.org ||Volume 8 Issue 04 Ser. I||April 2019 || PP35-42

Effect of Cognitively Guided Instruction on Primary School Teachers' Teaching Skills in Mathematics: Mombasa County, Kenya.

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ABSTRACT: *The study investigated the effect of Cognitively Guided Instruction on the teaching skillsemployed by primary school teachers to conductmathematics lessons.The Cognitively Guided Instruction (CGI) focuses on the need to understand the cognitive development process of the learner and use it to plan instruction.Indeed the CGI is designed for young children and hence the study focused on Early Childhood Education (ECE). The ex post facto research design was used for this study with the experimental group being drawn from the teachers enrolled for the Programme for Teachers of Mathematics (PTM); a professional development programme conducted by the Aga Khan Academy Mombasa and whose focus was the Cognitively Guided Instruction (CGI) training. Purposive sampling technique was used to select 16 teachers into the experimental group and consequently the matched pair design was used to select 16 teachers into the control group. The data was collected using the Lesson Observation Schedule over a period of four months with each participant being observed twice. In order to check for differences between the experimental and the control groups, a Mann-Whitney U test was usedand the hypotheses tested at a significance level of 0.05. The study established that the CGI had a significant effect on Teaching Skills used by primary school teachers during mathematics lessons. The results of the study are of benefit to teachers, parents and other education stakeholders as it provides empirical evidence on the effect of CGI training in a context fundamentally different from the contexts in which the CGI was developed. It is also beneficial to teacher trainers as they consider methods of maximising the training outcomes of primary school teachers. For policy, the study recommended that the CGI should be integrated into pre-service teacher training programmes and in-service workshops for teachers already in the field. The study also recommended, for further studies, an investigation be done into the relationship between use of CGI methods and achievement of learners in mathematics examinations.*

KEYWORDS:*Cognitively Guided Instruction, Teaching Skills, Problem Solving. Mathematical Thinking, Early Childhood Education*

Date of Submission: 03-04-2019 Date of acceptance:19-04-2019

I. INTRODUCTION

Research in Mathematics Education is preoccupied with exploring how to develop student teachers' understanding of mathematics and convincing them to teach mathematics for understanding (Llewellyn, 2012). The degree to which the function and benefits of mathematics are realised depends heavily on how learners are introduced and exposed to mathematical concepts and how they engage with the subject. This outcomecan only be achieved if learners are engaged in exploring mathematical ideas through problem solving, working with complex situations in which they formulate and model problems, screen relevant from irrelevant information, organise information, make conjectures and test their validity(Putman, Heaton, Prawat&Remillard, 2007).

Arguably, the dynamic demands of the society require that learners be prepared to understand mathematics while at the same time develop capacity to use and communicate mathematics in their current and future lives (Sierpinska& Kilpatrick, 2012). Mathematics must be taught in a way that leads to conceptual understanding and this entails creating an environment where learners are actively and intellectually involved. This position is an apt response to the misconception that the degree and quality of learning of mathematics automatically occurs when learners engage in activities. Putman et al. (2007) highlight the significance of the intellectuality of the activity. In support, Wessels (2008) singled out two factors that are most critical in blocking conceptual understanding. These are: the poor content knowledge demonstrated by teachers and poor teaching strategies that do not cater for the diverse needs of the pupils. The two factors are key among the contributors to the low achievement of pupils in mathematics. In Kenya, the Ministry of Education Science and Technology (MoEST) opines that the low achievement of pupils in mathematics is due to the fact that most of the teachers are unskilled, incompetent and lack expertise since most of them obtained poor grades in Mathematics at the Kenya Certificate of Secondary Education (KCSE) mathematics examinations

(MoEST,2011). This position confirmed an earlier finding by Agyenmang (1993) that there is a direct correlation between the understanding of the teacher and that of the learner. Thus, the focus on improving the conceptual understanding of the learner is futile if done without addressing the conceptual understanding of the teacher. Preservice teachers would benefit from a curriculum designed/redesigned to respond to this critical need. However, even if that were possible, many teachers already in the field continue to use methods that do not necessarily build conceptual understanding and yet are expected to mentor newly graduated teachers. The issue then becomes how to help the in-service teachers develop the requisite conceptual understanding.

Carpenter, Fennema, Franke, Levi and Empson (1999) contend that young children are naturally curious and begin to engage with mathematical concepts, like counting, way before they get into school. According to them,the way children solve the daily life problems and their ability to solve problems posed to them is an indication of their mathematical thinking. This intrinsic ability needs to be carefully tapped and guided to provide the young children with high-quality early mathematics instruction. Arguably, school mathematics must be structured with the knowledge that children learn best when they build concepts from their intrinsic mental framework. Learning is most effective when it builds on previously learnt ideas and this will only occur when children do not perceive the ideas presented to them as foreign and lacking connection with what they already know. A clear link between 'life' and mathematics must be developed as the young ones are introduced to the subject known as mathematics. It is on this basis that Carpenter, Fennema, Peterson and Carey, (1988) conducted a research on how the thinking of children could be used to make teaching and learning of mathematics more meaningful. Out of their research, they developed the Cognitively Guided Instruction (CGI).

Interventions designed to address challenges in the teaching and learning of mathematics must take into consideration the curriculum that is used in the early years of learning. This is because the learning that takes place in the early years has permanence that significantly affects any future learning (Dembele&Lefoka, 2007). This study considered the philosophical foundations of Early Childhood Education (ECE) built around the Waldorf movement, the Developmentally Appropriate Practice (DAP), Reggio Emilia and High/Scope models. Each model has a unique feature that informs and complements the Cognitively Guided Instruction (CGI). The Waldorf movement, envisions holistic education as that which focuses on the head, hands and the heart ; DAP includes among others: promotion of children's active exploration and interactions with others; use of observations of children's individual interests and developmental progress to plan the curriculum; the Reggio Emilia model is based on the philosophy that children are active constructors of their own knowledge and the High/Scope model has its foundation on Piaget's constructivist theories of child development. The fundamental premise of High/Scope model is that children are active learners who learn best from activities that they themselves plan, do and reflect on (Morrison, 2007; Gestwicki and Bertrand, 2011).

All the mentioned models are of a constructivist nature and use the context of the learner as emphasized by the CGI. Due to the alignment between CGI and known theoretical foundations of Early Childhood Education, it would be reasonable to expect positive results with regard to instructional approaches used by the teachers. However due to the fact that CGI is, by design, contextual, it was necessary to determine its impact in a context largely different from the one in which it was developed and has been tested.

II. METHODOLOGY

The study used the ex post facto research design. Specifically, the study used the criterion-group (also known as the causal-comparative) type of the ex post facto design; the criterion in this case being the Cognitively Guided Instruction (CGI) training. The data was gathered using the Lesson Observation Schedule and analysed using both descriptive and inferential statistics. A sample of 32 subjects (16 subjects in the experimental group and 16 in the control group) were selected for the study by using the purposive sampling technique. A test at 0.05 significance level was done to the hypothesis: The CGI has no effect on primary school teachers' use of Teaching Skills during mathematics lessons. The Mann-Whitney U test was used to check if there were statistically significant differences between the experimental and the control groups with regard to teaching skills.

III. DISCUSSION

The Cognitively Guided Instruction (CGI) is an inquiry-based approach of teaching mathematics. It provides teachers with knowledge about the developmental stages of children's mathematical reasoning. This enables the teacher to plan mathematics instruction based on their learners' understanding and consequently guide them through greater mathematical reasoning and concept mastery. In a CGI classroom, time is dedicated to learners engaging in problem solving and are not told how 'to do' mathematics. The latter entails providing learners with a formula, showing them how to apply and asking them to apply it whether they understand it or not. The learners in a CGI classroom are taken through an open-ended experience whereby they mostly have more than one way of solving the problem before they report their solutions to peers and the teacher. This

provides a perfect opportunity to correct misconceptions and structure instruction to enable the children to learn. In controlled studies conducted in the United States of America, CGI teachers taught problem solving significantly more and number facts significantly less, than teachers in the control group (Chambers &Lacampagne, 1994). Despite the agreement among most researchers that the CGI has clear outcomes with regard to learners' understanding of mathematics, some like Van den Heuvel-Panhuizen&Drijvers (2014) argue that the context of a child significantly affects their thinking. Building on this position, the researcher sought to establish whether there was a difference between the CGI teachers and the non-CGI teachers in Mombasa County with regard to the types of teaching skills used to facilitate the development of conceptual understanding among the pupils.

Cognitive Learning Theories

The learning theories on cognition focus on a number of factors including but not limited to active and passive learning, the concern for understanding, the role of prior knowledge, the cumulative nature of most forms of human learning, the role played by cognitive analyses of performance (Shuell,1986). Several theories have been put forth to explain how cognition happens, how children and learners in general develop cognitively. This covers the growth from rudimentary mental inclinations to complex processes developed through well thought out strategies designed to build on and reorganize the rich knowledge that children bring to school. Pritchard (2013) opines that theories on cognitive learning have proved effective in providing approaches to teaching over the years but in a large number of areas have been superseded by theories that take a broader stance on issues like mental activity, the importance of prior knowledge, social context and social interaction through the medium of language.

Berk (2006) postulates that cognitive development is mostly continuous rather than spasmodic and each individual learner develops uniquely. The teacher needs to consider this fact as they design the learning process so that the growth is not stunted by the application of an inappropriate order of activities. Recognizing that each learner possesses his or her individual thinking framework, each teacher is expected to structure instruction in such a way that each learner can make meaning of the subject and learn. This creates a complex situation, as teachers, just like learners, possess individual thinking frameworks and this affects their selection and application of teaching skills. The Cognitively Guided Instruction (CGI) model places emphasis on application of this principle in the teaching and learning of mathematics by emphasizing communication among the learners as a way of revealing their thoughts (Carpenter,Fennema, & Franke, 1996). Teachers must develop the required competence in detecting the indicators of mathematical thinking. Missing opportunities or inaccurate diagnosis of the learners' thinking may result in mental blocks thereby hindering the learning of mathematics.

The theories of Jean Piaget and Jerome Bruner formed a basis for this study and led to an exposition of the Cognitively Guided Instruction approach of learning of mathematics. Jean Piaget came up with a school of thought which postulates that cognition is based on organisation of, and adaptation to the perceived environment. While children do not use logic like the adults, their thinking becomes quite sophisticated as their learning takes root. They think problems through before acting (Trawick-Smith, 2014). They move beyond the concrete world and begin to think beyond objects or people around them and are able to reflect on things they cannot see, hear, touch, or act on. However, their thinking is heavily driven by their senses and this makes them susceptible to distraction by the appearance of things. Teachers need to understand that the problem-solving abilities of learners is often hindered by what they see, hear or touch (Trawick-Smith, 2014). On the other hand, this ability, when properly developed, can be useful in designing instructional sessions that will help the children to explore the world around them. The selection of what learners see, hear, touch or act on would therefore determine the quality of learning that would result from an instructional session. Piaget looked at intellectual development as a process that chronologically follows four distinct stages namely: the sensorimotor stage (from birth to 2 years of age); preoperational stage (2 to 7 years of age); the concrete operational stage (ranging from 7 to 11 years of age) and, finally, the formal operational stage which begins in adolescence and runs into adulthood. Piagetian thought has found wide application in the field of education. Perry, Docket and Harley (2007) argue that Piaget has forced the mathematics educator to closely examine the stages of intellectual development through which a child passes and use it to organise the mathematics curriculum.

Bruner identified three stages of cognitive development namely: the enactive, iconic and the symbolic stages. There is quite some similarity between Piaget's sensorimotor stage and Bruner's first stage (the enactive stage) which runs from birth to three months of age. During this period, the child engages in 'hands-on' activities and learning is through the manipulation of concrete objects (Martin, 2012). The Cognitively Guided Instruction uses this notion as teachers are forced to deliberately reflect on the children's thinking as they come up with the instructional procedures. Thus, teachers, aware that they should use concrete objects, avail manipulatives to learners during mathematics. The convergence of a teacher's understanding of Bruner's theory

and deep conceptual understanding of mathematics is demonstrated through the selection of pedagogical strategies that develop the required mathematical thinking.

The Cognitively Guided Instruction (CGI), just like Piaget's and Bruner's theories, focuses on the need to understand cognitive development and use this to plan instruction. It is a professional development programme based on an integrated programme of research focused on [a] the development of learners' mathematical thinking; [b] instruction that influences that development; [c] teachers' knowledge and beliefs that influence their instructional practices; and [d] the way that teachers' knowledge, beliefs, and practices are influenced by their understanding of learners' mathematical thinking (Carpenter et al., 1999).

Carpenter et al. (1996) in their analysis of learners' mathematical thinking concluded that children intuitively solve word problems by modeling the action and relations described in them. This research covered how the basic concepts of addition, subtraction, multiplication and division develop in children and how they can construct concepts of place value and multi-digit computational procedures based on their intuitive mathematical knowledge (Carpenter et al., 1996). Each pupil is encouraged to solve the problems in any way that she or he can. This leads to the development of specialised skills and ways of framing and solving problems that facilitate the building of confidence and competence (Ball, 1990).

Teaching Skills

Based on the nature of the study, the Teaching Skills were categorisedintosix clusters and this paper presents the findings on two of the clusters, namely:Lesson Introductionandthe meaningful use of manipulatives. The two clusters are used to show the common trend and is followed by a report on the results based on the overall scores on teaching skills covering all the six clusters.

IV. FINDINGS

Bio-data: The researcher found out that most of Early Childhood Education teachers in the geographical area of study were female. Indeed all the respondents for this study were female and this was not by design. Hence the bio-data analysis does not include gender consideration.

The distribution of teachers based on the classes taught were as in figure 1

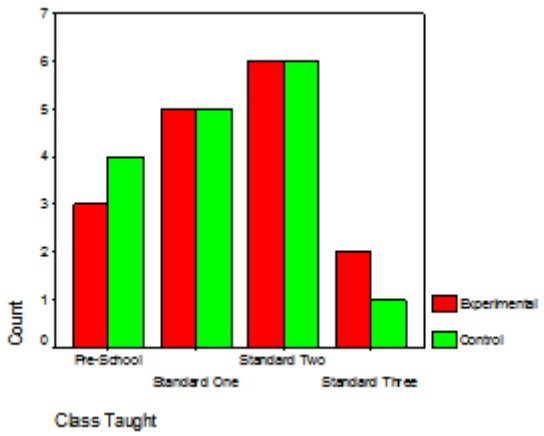

Figure 1: Classes taught

Professional qualifications was also an area of interest as it had the potential of contaminating the results. The results are in figure 2.

Professional Qualification

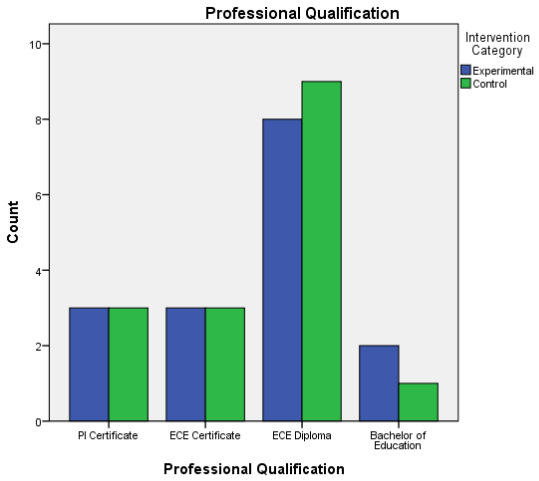

Figure 2: Professional Qualification

The results in figure 1 and figure 2 show that the members of the experimental and control groups were quite comparable, a clear result of the matched pair design that was used to obtain the control group. There is considerable similarity between the two groups in terms of classes taught and professional qualification. Combining the number of teachers holding Diploma orBachelors degree yields equal numbers from both groups hence resolving the apparent difference between the ECE Diploma holders and the Bed graduates as seen in the graph.

This was also the situation with regard to number of years of teaching as displayed in Table 1

Table 1Number of Years of Teaching

		Number of Years of Teaching			Total
		2-5 years	6-10 years	Over 10 years	
Intervention Category	Experimental	4	5	7	16
	Control	4	9	3	16
Total		8	14	10	32

The two groups were found to be suitable for the study as they were similar in all characteristics except the intervention (Cognitively Guided Instruction).

Effect of Cognitively Guided Instruction on Teaching Skills

The findings on the effect of Cognitively Guided Instruction (CGI) on Lesson Introduction and meaningful use of manipulatives are presented in Tables 2,3,4 and 5. This is followed by the results of an analysis of the overall scores of the Teaching Skills in tables 6 and 7.

Lesson Introduction

The interest of the researcher was on the level of creativity and the degree of learner-centeredness at the onset of the lesson. The presence of a story or a song to act as a hook into the lesson was desirable.

Table 2Teaching Skills- Lesson Introduction: Rank Scores

Teaching Skill	Category of participant	theN	Mean Rank	Sum of Ranks
Lesson introduced by a relevant song or story (hook)	Experimental	16	21.56	345.00
	Control	16	11.44	183.00
	Total	32		
Teacher deliberately gives the learners a chance to express themselves	Experimental	16	22.75	364.00
	Control	16	10.25	164.00
	Total	32		

There were apparent differences in the means of the two groups with the mean of the experimental group being higher than the one for the control on the two items in this category. In order to establish whether this difference was statistically significant, the Mann-Whitney U test was run and the results are in Table 3

Table 3Effect of Cognitively Guided Instruction on Lesson Introduction

	Lesson introduced by a relevant song or story (hook)	Teacher deliberately gives the learners a chance to express themselves
Mann-Whitney U	47.000	28.000
Wilcoxon W	183.000	164.000
Z	-3.280	-3.952
Asymp. Sig. (2-tailed)	.001	.000
Exact Sig. [2*(1-tailed Sig.)]	.002[b]	.000[b]

The second skill was on the use of manipulatives in delivering the lesson. The focus was on the relevance of the manipulatives in the context of the lesson taught and a summary of the descriptive statistics is presented in Table 4.

Table 4 Use of Manipulatives

	Category of the participant	N	Mean Rank	Sum of Ranks
Teacher meaningfully uses manipulatives in delivering the lesson	Experimental	16	19.63	314.00
	Control	16	13.38	214.00
	Total	32		

The results in table 4 show a difference in the mean ranks of the two groups with the experimental having a mean rank of 19.63 and the control 13.38. A test on the significance of this difference is presented in table 5.

Table 5: Use of Manipulatives- Mann-Whitney U test results

	Teacher uses manipulatives in delivering the lesson
Mann-Whitney U	78.000
Wilcoxon W	214.000
Z	-2.064
Asymp. Sig. (2-tailed)	.039
Exact Sig. [2*(1-tailed Sig.)]	.061[b]

From the results displayed in Table 5 (U= 78.000, P=0.039,), it is apparent that there were differences that were significant at α=.05. The researcher observed that a number of teachers used the manipulatives extensively but without any clear bridge to connect the activity with the concept under study. Members of the non-CGI group explained that the use of manipulatives was a key expectation in teaching mathematics in lower primary and pre-school. Whereas teachers from both groups had manipulatives which they mostly used to solve problems involving the understanding of the number concepts, the way in which they were used was clearly different. Teachers in the CGI group modelled their teaching along the strategies put forth by Carpenter et al. (1999) According to Laski, Jor'dan, Daoust and Murray (2015), even though manipulatives are ubiquitous in early childhood classrooms, outcomes regarding their efficiency are inconsistent. A study of two school districts in America found that every elementary teacher reported using manipulatives nearly every day (Uribe-Florez& Wilkins, 2010).

Teaching Skills-Overall Scores

Working with the cumulative totals of all the teaching skills under study, the results obtained are shown in table 6.

Table 6Cumulative Results on Teaching Skills

Ranks				
Teaching Skills	Category of the participant	N	Mean Rank	Sum of Ranks
Cumulative	Experimental	16	24.50	392.00
	Control	16	8.50	136.00
	Total	32		

Theexperimental group returned a mean of 24.5 while the control had a mean of 8.5. The outcome of the test of significance is presented in the Table 7

Table 7:Teaching Skills-Overall

	Teaching Skills Cumulative
Mann-Whitney U	.000
Wilcoxon W	136.000
Z	-5.568
Asymp. Sig. (2-tailed)	.000
Exact Sig. [2*(1-tailed Sig.)]	.000b

The results in Table 7 show that the Teaching Skills employed by group of teachers who had undergone the Cognitively Guided Instruction training were significantly different ($Z= -5.568$, $p< 0.05$) from the ones employed by the teachers in the control group.

V. CONCLUSION

The Cognitively Guided Instruction had a significant effect on a majority of teaching skills. These included teaching skills employed at different stages and covered different aspects of the mathematics lesson including: lesson introduction, lesson development, use of manipulatives, the application of collaborative learning approaches, creation of a conducive learning environment and effective use of questioning techniques that leads to discovery of knowledge. With regard to lesson development, it was established that most CGI teachers used a hook in the form of a story or a song to meaningfully generate and sustain learners' interest in the lesson and that learners were deliberately given a chance to express themselves.

Further, on the use of manipulatives, teachers from both groups used manipulatives in most of their lessons. The interest was in the meaningful use of the manipulatives and this is where the CGI group displayed superior skills.

The study concluded that the Cognitively Guided Instruction had an effect on the application of Teaching Skills during a mathematics lesson. The teachers who had gone through the CGI training used superior teaching skills that promoted independent learning and meaningful inquiry.

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