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Communication Tools and Methodologies for Mathematics Instruction

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ABSTRACT This paper presents Communication Tools for Maths (CTM) and Get Real Maths (GRM), which are Active/Communicative Methodologies (ACM) for mathematics teaching in the Science, Technology, Engineering, Mathematics / Science, Technology, Engineering, Art and Design, Mathematics (STEM /STEAM) Education era in Zimbabwe.Observation of maths instruction in schools, remedial education centres and archival research was conducted. CTM and GRM were constructed through conflation of mathematics methodologies and active methodologies for language teaching.CTM and GRM were tested in a pilot programme.Quantitative and qualitative analysis occurred.Assessment of the potential contribution of ACM to maths Curriculum Development, Continuous Professional Development (CPD), Mathematical Knowledge for Teaching (MKT) and teacher training was initiated.The findings reflected that CTM and GRM increased communication in maths classes and that diversified instruction and active methodologies are relevant to Curriculum Development, CPD and MKT in Zimbabwe.Recommendations for further development of CTM and GRM have been made.

INTRODUCTION

CTM and GRM have been developed within the framework of the ongoing Active/ Communicative Methodologies (ACM) project (Azevedo 2013) initiated in Zimbabwe in 2011. ACM are adaptable didactic approaches which integrate elements of active methodologies and communicative approaches for teaching, The Seven Essential Skills (Wagner 2008) and the Scientific Method (Gauch 2002). The researcher proposes ACM as purpose designed methods for the instruction of STEAM subjects. The testing of two products of the ACM project, CTM and GRM, was undertaken for the first time in 2014.

The development of CTM and GRM is situated within the context of curriculum development triggered by the Zimbabwe government's prioritisation of STEM Education in alignment with the African Carribean Pacific (ACP) Group of countries (Azevedo 2013). The Curriculum Reform process is ongoing (Azevedo 2014) and implies the introduction of new systems for STEM / STEAM subjects: "[…] new curricula generally entail new approaches to teaching and learning […]" (Paulsen 2015).

Therefore CTM and GRM link directly to curriculum associated fields. They also correlate with national and international research on Mathematics Continuous Professional Development (MCPD) (Jojo 2015) or CDP (Kaino 2015; Paulsen 2015; Rogerson 2015; Yacoubi 2015) and MKT (Kaino 2015).

This paper outlines select information regarding research objectives, phases and methodologies, conclusions and recommendations. Three samples of CTM and one sample of GRM application are sketched in this paper.

Relevance of CTM and GRM to Current Research

Current research (Jojo 2015; Paulsen 2015; Rogerson 2015; Yacoubi 2015) reflects that teachers are central innovators of education. Therefore, professional development programmes that support the process of cultivating innovators is essential.

Teaching methodologies and approaches are integral to MKT (Kaino 2015) for teachers. MKT includes knowledge of topic content, ways to teach curriculum content and teaching strategies – methodology - combined with knowledge of students background (Kaino 2015). The important of understanding a student's background is recorded by da Ponte (Ponte 2012) with reference to the introduction of a new maths curriculum in Portugal (Ponte 1992, 1994, 2012).

Relevance of CTM and GRM to Research in Zimbabwe

Teacher development in Zimbabwe has consisted mostly of courses, training programmes, conferences, mentorship and higher degrees (Jojo 2015). Questionnaires processed in CTM and GRM reflect that many teachers do not prioritise learning 'new' methodologies after Teacher Training College. According to observations and documentation of the first 2015 phases of the CTM and GRM project, MKT and CPD would need to identify strategies for catalysing change in teacher's attitudes, beliefs and opinions about teaching as well as views regarding their subject and students.

Relevance of CTM and GRM to International Research

There is relevance to numerous international research projects but only a few will be mentioned in this paper.

Morocco

Reflections on CPD were triggered by the need to adopt 'learn by doing' teaching and learning strategies (Yacoubi 2015). The importance of 'mathematics education skills, educational methodologies,' in the framework of MCPD is fully recognised. Current mathematics education policies in Morocco aim to 'improve the curricula, [initiate …] new educational methodologies and tools' (Yacoubi 2015) useful for teaching and learning maths.

Portugal

The current maths curriculum has been compulsory for schools since 2010 (Ponte 2012). The example of Portugal is of international importance as the process of curriculum change and the experience of teachers and education experts in the county is well documented. The new curricula integrated interdisciplinary activities, the provision of multiple entry points for maths activities for learners, holistic thinking and reinforcement of previous learning (Ponte 2012). The promotion of learning maths and student's ability to use it in different contexts was also a priority (Ponte 2012).

Methodological guidelines were preferential to exploratory approaches for maths (Ponte 2012). Teachers interviewed about the experience of teaching a new curriculum commented on the importance of training, preparation and well-coordinated use of resources (Ponte 2012). One recorded comment was that there were 'insufficient methodological guidelines' (Ponte 1994), implying the role of methodologies in curriculum change and pilot programmes.

Schools are the recommended drivers of innovative movements in education in Portugal and the change of professional culture (Ponte 2012). Changes in professional culture should be structured and systematised for the best possible results (Ponte 2012).

CTM and GRM retained many factors of the new curriculum development in Portugal: inclusion of student contextual information and views in the sessions and the aim to escape from 'computational procedures or axiomatic constructions' (Ponte 1994). The creative thinking behind GRM intends for learners to conceive of maths as 'a dynamic science' (Ponte 1994), a living and real entity rather than a dry 'school discipline' (Ponte 1994).

CTM and GRM development also retained 'integrating knowledge of mathematics with knowledge about the students taking into account the learning processes and specific knowledge about student's culture and preferences as well as current mathematics understandings.' (Ponte 2012).

South Africa

A good example of leadership is the movement for change in teacher's attitudes, beliefs and perceptions about maths and maths education (Paulsen 2015). Paulsen puts teachers at the centre of reformative processes and places a high value on teacher's contributions to building the education system. 'Teachers are agents of change' (Paulsen 2015).

CTM and GRM converge with research on situated learning (Paulsen 2015) which posits that knowledge and learning are constructed through participation in community discursive practices.

Need for Active Methodologies for Maths

Interdisciplinary cooperation is recommended for the construction of methodologies for maths: Civil (2008) states that there is "[… a] need for interdisciplinary teams with expertise in different areas including mathematics education, immigration policy, linguistics, socio-cultural theories, anthropology, just to name a few. […] as well as for the development (or refinement) of theoretical and methodological approaches."

CTM and GRM integrate Linguistics and are creative constructs which aim to solve problems entailed by the requirements of the Informatics Age (Azevedo 2013).

Objectives of CTM and GRM Research

Numerous objectives directed the CTM and GRM projects.

Academic Objectives

The interdisciplinary conflation of one selected methodology for maths with active methodologies and communicative approaches for teaching second languages was paramount.

Alignment with the principles of active learning in STEM / STEAM Education (Larson 2002) was an essential objective.

Demonstration of the innovative/creative potential of the Essential Skills was a third objective. Essential Skills only were used for the creative processes of the research.

Pedagogical Objectives

Primarily the researcher aimed to increase communication in maths classes by using Active/Communicative Methodologies (ACM) which integrate discursive activity. Discursive activity involves learners and teachers participating in a "community of practice" (Moschkovich 2007) CTM and GRM focus on community/class communication for increased effectiveness in maths teaching and optimum results in maths learning.

The secondary objective was to increase the rate of understanding of maths in bilingual participants or participants who spoke very little English through application of ACM.

Thirdly, the researcher aimed to use ACM to increase the rates of interest and performance in maths in learners who did not like, understand or engage with the subject and had documented poor performance in maths. ACM was also intended to provide learners with different entry points and strategies for tackling maths problems.

The fourth objective was to test the applicability of diversified instruction for maths in Zimbabwean classrooms. In the first 'Observation' phase of the project, a lack of variety in the use and knowledge of teaching methodologies, approaches and materials was noted.

Formative Objectives

2012 – 2014: the development of ACM was primary. In 2015, the goal was to assess the potential for incorporation of ACM into MKT and CPD.

Reformative Objectives

2014: Assessment of the potential to expand existing maths curricula as a result of applying ACM was paramount throughout. The researcher aimed to identify secondary school topics that could be taught in primary school using ACM, for example, Pythagoras Theorem.

Secondly, the researcher aimed to identify areas of potential expansion in teacher training MKT and in CPD.

2015: The researcher aimed to conduct surveys regarding the knock on effects of using ACM in classrooms. A central research question was: to what extent do changes in methodology entail changes in the presentation and definition of maths?

The researcher aimed to identify aspects of teacher's and learner's attitudes and knowledge that need to change to meet the mandate of STEM / STEAM Education. Finally, the researcher aimed to conduct a survey regarding the adaptation of materials, curricula and certification systems for maths which correspond to ACM. The research question was: does a whole alternative system for maths education need to be developed as a result of applying different teaching methodologies?

Summary of the CTM and GRM Project

Phases 1 of current research are ongoing for 2015.

Phase 1 – Research and Observation

2014: This phase consisted of archival research and the observation of teaching and learning practices currently applied in 50 government schools and 50 private schools. Top down teacher to learner instruction during 25 minute lessons and rote learning was noted. Analysis of school reports revealed that 58.2 percent of learners in the participating schools had a low performance in maths and language.

Phase 2 – Theoretical Review

2014: Selection of appropriate theories of Linguistics, teaching methodologies and approaches was effected. Theoretical components for communication and for maths were conflated into design models for CTM and GRM. Checklists for tool and methodology adaptation were formulated.

Phase 3 – Development of CTM and GRM

2012 - 2014: The rationale for developing tools for maths was based on Silver et al. Tools are ‘excellent techniques for helping teachers increase student engagement, differentiate instruction, and design comprehensive lessons and units. [They are] effective options for formatively assessing student progress and integrating technology and multimedia into the classroom’ (Silver et al. 2012).

The ACM referred to as Get Real Maths (GRM) was adapted from the Communicative Approach for second language based on the rationale that activity promotes in-class communication (Moirand 1990; Goanach 1991). Nkopodi and Mosimenge discuss the learning and communicative value of indigenous games like *morabaraba* in maths classes (2009) and cite Ascher (1991:85), Bright et al. (1985), Fletcher (1971), and Guy (1991). ‘As people engage in any game, the language, vocabulary, mathematical skills and a variety of mathematical activities are generated. Although some of these aspects may be very basic, they serve as important components in the development of mathematical concepts’ (Nkopodi and Mosimenge 2009).

Phase 4 – Testing CTM and GRM

2014: CTM and GRM were tested in a purpose designed private classroom with STEM / STEAM Education materials, computers and ‘context’ areas where learners could display pictures or objects to stimulate discussion on maths topics.

One thousand randomly selected learners aged between seven and nine, equally sourced from government and private schools, commuted into classes of up to twenty five participants. Sessions lasted from sixty to ninety minutes. Teaching was conducted by the researcher who was observed by a total of 250 teachers from government and private schools at different times.

Phase 5 – Assessment

2014: Qualitative and quantitative analysis was undertaken. Questionnaires were prioritised, followed by analysis of written classroom activities and homework. Video and audio recordings were analysed. Questionnaires completed by observing teachers were analysed.

2015: To date only the questionnaires on learner’s current ability in maths have been analysed. Results are given under the ‘Observations’ section in this paper.

METHODOLOGY

Phase 1 – Observation and Archival Research

Observation in schools could only be recorded by notes. Surveys for teachers, learners, head teachers and auxiliary staff in the participating schools were conducted by questionnaire and recorded interviews. Standard archival research was conducted.

The researcher set the specific areas of investigation: participants learning styles, ability in maths, feelings towards maths, perception of maths, achievement in maths, to name a few. Terms and conditions for classroom conduct and legal issues were listed. Disclaimers and consent forms were issued.

Phase 2 – Selection of Theoretical Components of CTM and GRM

Design models for CTM and GRM were formulated and appropriate theoretical components were selected for inclusion. The prioritised elements are as follows:

Linguistics and Applied Linguistics

Functional Systemic Linguistics emphasises the importance of context: sense is made in context and therefore context facilitates understanding (Eggins 2004). The use of context in CTM and GRM aims to provide learners with real life frameworks which integrate factors of their own background.

Phonetics carries sense and emphasis. Phonetics makes communication effective and supports understanding (Carton 1974; Saussure de 1972; Martinet 1989).

Discursive activity: 'an intellectual practice requiring a social use of signs and the understanding of their meanings' (Radford 2001; Moschkovich 2007).

Established Methodologies for Maths Instruction

Only one methodology was retained: Larson's didactic guidelines for maths instruction: "There are five essential characteristics of effective mathematics lessons: the introduction, development of the concept or skill, guided practice, summary, and independent practice. There are many ways to implement these five characteristics, and specific instructional decisions will vary depending on the needs of the students, the objective being taught, available resources, and teacher preference, but all five characteristics are always present" (Larson 2002).

Communicative Approach for Second Language Teaching

Discursive activity is inherent in the Communicative Approach methodology for language: Exposure to the element/topic that must be learned through recordings, videos, or other demonstration; Repetition of the element; Explanation of the topic; Activity and Re-utilisation to practice and use the element or topic; Reinforcement – homework or other means of revision to promote long term or permanent knowledge of the topic (Moirand 1996).

Scientific Method

The researcher prioritised the reasoning systems of the scientific method: deduction, induction, qualitative and quantitative analysis (Gauch 2002).

STEM / STEAM Skills

Skill 5, Effective oral and written communication skills is a language skill (Wagner 2008) and Skill 1, critical thinking and problem solving are maths skills (Wagner 2008) The Essential Skills take account of both communication and mathematics skills.

Examples of CTM

Three examples out of the total one hundred and seventy five CTM designed between 2012 and 2014 are presented in this section.

Non-Verbal Communication

Sign systems or semiotic systems are binary entities composed of content and expression. Content is the message, expression is the vehicle conveying the message: a red traffic light expresses the message 'STOP'. Semiotic systems are arbitrary social conventions established by socio-cultural groups (Eggins 2012).

Non-verbal Communication Tools for Maths are designed to convey instant messages to learners using non-verbal symbols or signs. Maths already has a specific internationally coded system of non-verbal signs: =, +, - , <, >.

Some CTM's developed for learners in Zimbabwe are *Maths Symbols* and *Mental Maths, Semaphores and Flags, Prime Numbers* ***Nodo***, (an indigenous Shona game).

Maths Symbols – Pythagoras Theorem

The class was split into 4 groups. Context was created by doing a drill on the times tables using only numbers being multiplied by themselves, that is, 3 x 3= 9, 4 x 4 = 16. A series of carefully designed discovery activities based on the times tables drill led to induction of Pythagoras Theorem. Participants formalised their insights using a multiple choice questionnaire. They wrote a guided story about their discovery of Pythagoras Theorem.

The Tchokwe indigenous system conceptual illustration of Pythagoras Theorem was presented on completion of the exercise for reinforcement (Kaino 2013). The linear arrangement of dots representing the dimensions of each side of the hypotenuse triangle allow the rule to be instantly understood either on sight or by manually counting the dots.

Comments

Communication throughout the session was intense. The inductive style of the discovery activity engaged all participants without exception. Drawing the symbol facilitated rapid access of the rule.

Maths Symbols were also tested in multilingual classes. Non-verbal language, and drawing activities made mathematics information accessible to students with limited understanding in the official language of the class, English.

Intonation Tool for Maths – Nursery Rhyme

Nursery rhymes are easily retained cultural texts which use rhythm to promote long-term memorisation (Carton 1974). The use of *Nursery Rhymes* Maths Tools was tested on Shona speaking participants who had limited performance in English and immigrant participants. A nursery rhyme on maths procedures in Chinese was developed in 2014 with a group of Chinese children with minimal English who attended twenty 'Intonation' sessions. Non-verbal communication tools were also very effective with the Chinese group.

A session on estimation was conducted using Heinrich Hoffman's slovenly, hygiene-free character Struwwelpeter to create context. Estimations of the length of hair and length and breadth of Stuwwelpeter's finger nails was effected. Participants compared resulting estimations to their school standards for length of hair and nails. The activity underlined the relevance that mathematics holds for real life, in relation to personal hygiene!

One participant produced this nursery rhyme to reinforce the maths vocabulary of the lesson:

Struwwelpeter was a boy whose nails were metres and metres long!

He wouldn't cut his hair which grew ten millimetres a day,

And he was surprised that nobody would come over to play!

Breadth and width and length of hair and nails gave Struwwelpeter an awful pong!

Learners discussed the importance and real life significance of measurements and their function in building, manufacturing, architecture, engineering, fashion, food and beverages. This approach is slightly different from functional maths which focuses on maths used in daily life. CTM and GRM use real life contexts to make maths meaningful and relevant to individuals, using their own contexts and experiences as much as possible.

Comments

Communication was intense throughout the session.

The introduction of a morally didactic text from a different culture was effective. On other occasions, Shona, Ndebele and Chinese tales were used to put maths in context and approached the maths topic from a different angle. The use of these cultural texts was found to provide new points of access into mathematics topics. Some socio-linguistic research was required to achieve this, but it was found to be fruitful and worthwhile as it engaged the learners and valorised their cultures of origin (Civil 2008).

Verbal Communication

Verbal Language Maths Tools:
Maths Neologisms

Neologisms for maths were created by working with concepts and ideas. The concept of addition is to make more or increase numbers by putting more in. A neologism for addition could be something like 'volumising' or 'big-making' 'more-making', 'putting-more-in' for example. The exercise was very useful in that some neologisms suggested for addition like 'volumising' also made sense for multiplication.

Comparative mathematics discussions ensued: participants explained the conceptual and procedural differences between addition and multiplication. Communication was intense. Rote learning was challenged through demonstration, activity and discussion.

This multi-phased tool led to the development of glossaries of maths vocabulary – similar to Maths Tools 'Glossaries' and 'Vocabulary Organisers' (Silver et al. 2012).

Get Real Maths (GRM)

Get Real Maths integrates indigenous and STEM materials in the classroom for increased communication and the creation of contextual links between maths topics and real life. GRM is similar to applied maths, but is focused more on setting maths topics in relevant contexts, including the contextual background of learners, and the use of activities to facilitate understanding of topics.

GRM can also integrate CTM for reinforcement or memorisation. The use of activities and games in the Maths classroom is already recognised and becoming institutionalised through the use of Maths tools advanced by Silver et al. (2012) and Kaino (2013).

Nkopodi and Mosimenge (2009) refer to the value addition of curriculum materials for activities like 'fish rack construction, egg gathering, salmon harvesting and star navigation' into the curriculum in Alaska: integrating indigenous culture and real life principles and contexts into mathematics instruction. This contextual approach was highly valued in the design of GRM by all observing teachers without exception.

One objective of the Get Real Maths methodology is to facilitate recognition of maths in daily life contexts. This is similar to the 'seeing in/seeing as' exercise posited by John Berger (Berger 2008). For example, in one activity, participants were asked to identify the maths topics they could 'see in' (Berger 2008) a picture frame. The groups saw Pythagoras Theorem, geometry, surface area, measurements, dimensions, multiplication and addition, in the frame.

Presentation of GRM

GRM applies the methodological approach COATERM – Context, Objective, Activity, Task, Explanation, Repetition, Memorisation, to structure the lesson and focus instruction on the different foundational theoretical and didactic components. These elements are interchangeable within the lesson plan.

Context – putting maths in real-life contexts and situations for recognition of maths in the environment, careers, real life objects and applications. The researcher considered 'Context' to include information about the background of learners.

Objective of Communication – identifying the best type of communication method for the activity: verbal and or non-verbal, intonation or combinations of two or all three types.

Activity – discovery activities designed to provide a point of access to a mathematics rule, concept or procedure.

Task – Larson's maths instruction phases 'development of the concept or skill', and 'guided practice' (Larson 2002) is pertinent in this section. Relevant STEM / STEAM skills and materials linked to the topic are identified for development of activities, worksheets and projects. Deductive and inductive reasoning activities/tasks are defined.

Explanation – following the activity and task sections, participants explain the topic in their own words. The teacher comments, makes additions and corrections as appropriate. This corresponds to the 'Summary' lesson stage in Larson's prescribed practice (Larson 2002).

Repetition / practice – sums, quizzes, maths tools can also be used here for classwork or homework.

Memorisation: Story, Song, Rhyme, notes, text book, maths took, an activity from CTM can also be used here. The memorisation stage can be covered by homework.

Either Repetition or Memorisation phases or both can conflate into Larson's 'independent practice' (Larson 2002).

2014: COATERM was applied to integrating the indigenous game and materials *Nodo* into an activity called *Nodo Accounts*. The topic of accounts was requested by learners who had initiated a discussion on the 'real' maths applied in their parents businesses and a project on Stem Skill 4, Initiative and Entrepreneurialism that was being developed in the 'Contexts' section of the classroom using STEM / STEAM materials.

Nodo involves pulling stones in and out of a circle drawn on the ground, a direct match with the concept of money going into and being withdrawn from a bank account. The class was shown a set of accounts set out in two columns before the exercise. The activity drew visual parallels between the inflows and outflows of money in an account. They were then given sets of stones and had to draw up a basic balance sheet using the stones, the game and a prepared worksheet to make the calculations. The activity was very challenging but the groups persevered and one group did manage to make their accounts balance.

GRM and CTM were found to be adaptable to any primary school topic. For High school, a list of topics was drawn up to reflect topics which worked well for maths instruction focusing on procedures: Factor and Remainder Theorem, Binomial Expansion, Partial Fractions, Trigonometry, Differentiation, Integration, Differential Equations – and for maths instruction focusing on rules: Exponentials and logarithms, Partial Fractions, Trigonometry, Complex numbers (step-by-step instruction makes no sense at all!), Vectors (again, step-by-step instruction makes little to no sense), Sequences.

OBSERVATIONS

This paper records findings for the first pilot programme for CTM and GRM in 2014. The 2015 project is in course.

Initial Status 2014

Opening questionnaires on 1000 participants views on maths established the following: *Group 1 - 41 percent* of the group, precisely 410 individuals 'hated maths' were 'afraid' of it, found maths 'difficult', 'got bored' with maths, 'had trouble doing homework'. Examination of six sets of school reports of this group indicated variable poor to average performance in maths.

Group 2 - 40 percent, precisely 400 individuals 'loved maths', 'understood maths without problems', 'didn't need help with maths'. Six set of school reports of this group indicated consistent good to excellent results in maths.

Group 3 - 19 percent of learners, precisely 190 individuals 'found maths difficult' 'had extra lessons' and had acceptable performance contingent on assistance. School reports indicated average to good performance in maths.

Questionnaires and observation for learning styles established that in this group, 327 individuals had a predominantly deductive reasoning style. 431 individuals had a largely inductive reasoning style and 242 had a combined inductive/deductive learning style.

Final Status 2014

It has been observer that 74.6 percent of Group 1 participants had improved understanding of maths topics. In group 3, 88.3 percent experienced improved performance in maths. All participants stated that non-verbal CTM facilitated long-term engagement and integration of rules and topics in maths. Of the 41 percent that hated or feared maths, 85.2 percent improved their results in school homework and class performance during the study. Fifty-eight percent of this group reported that they had started formulating their own games to help them 'understand' their formal school homework and maintained an improved performance in class and homework in the six months following their participation in the study.

Interdisciplinary approaches were successful as 92 percent of the participants noted that it made the sessions more enjoyable, they 'remembered more' and they 'liked learning more than just maths'.

Multi-cultural multi-lingual integration was a popular approach. The use of the indigenous game *Nodo* was very popular and the Shona learners enjoyed the valorisation of their cultural system (Civil 2008). Learners from other ethnic groups (40% of the group) said that they had never previously understood the game but liked it. This 40 percent suggested other uses for the game in maths instruction: mental maths, an adapted abacus tool, learning fractions.

Multi-cultural material increased understanding in Group 1 by 31.7 percent because they became more engaged by the tool and said they 'thought more about what they were doing in maths' as a result. They also said that the multi-cultural or multi-lingual elements of the class helped them remember the rules better and 'think about maths by thinking of something else interesting'

The integration of linguistics improved communication in the classroom. Discursive activity led to improved understanding because the children were able to use their own language(s) to learn maths rather than listen to the teacher's language about maths. This was true for 91.7 percent of Group 1 participants and 82.3 percent of Group 3 participants. The remaining 8.3 percent of Group 1 participants and 17.7 percent of Group 3 participants stated that they liked maths more but still found it difficult.

In Group 1, 34.1 percent of participants said that they found it 'helpful to think in a different way about maths'. Inductive reasoning styles were found to promote understanding because they approached maths from an angle that made sense to the group of inductive style learners in the pilot programme.

The use of inductive reasoning processes in CTM and GRM increased the rate of understanding of maths topics in 'inductive' learners by 87.6 percent in combined Group 1 and Group 3 analysis.

Participants Responses 2014

All participants enjoyed the activities and discovery process of the COATERM models. The unanimous response of the learners could be attributed to their age (seven to nine years of age): they were open to different approaches, willing to experiment and wanted to have as much fun as possible in lessons. The researcher notes that group dynamics vary.

Teacher's Responses 2014

All the observing teachers favoured the ACM, saying that putting maths in the context of other subjects or fields was 'a good preparation for careers' and 'made maths concrete rather than completely abstract' for learners. The teachers noted that the use of interdisciplinary approaches and materials increased understanding as it gave learners 'anchors in real-life to help them access abstract theories', but it needed detailed and intensive training and what they called 'lateral thinking' on the part of teachers.

The use of context based activities designed to promote understanding and approach maths from a different angle or point of access that suited learners' personal reasoning or learning style was favoured by 100 percent of observing teachers.

Although the teachers liked the approaches, they stated that they didn't feel they would be able to apply those methods without some years of training and research. Similar comments were made by teachers in Portugal: some expressed feeling of insecurity about applying new methodologies (Ponte 1994).

Also similar to experiences in Portugal were comments that the content of CTM and GRM sessions was not 'true maths' or proper maths' as in the 'school discipline maths' (Ponte 1994). One teacher in Portugal remarked 'this was not mathematics but something else'.

These comments provoked reflection on the ways in which changes in methodology imply the construction of an entire system and network of applications corresponding to that methodology, making it a fully operable and solid entity capable of holding its own for the long term. Similar considerations are expressed by da Ponte (Ponte 1994, 2012).

Initial Status 2015

The questionnaires and research formats include relevant elements proceeding from 2015 archival research.

Evaluation in Relation to Recent Studies

Again the CTM GRM research has been strongly creative, but has reinforced direct links to the findings of researchers focusing on CPD and MKT.

DISCUSSION

Evaluation in Relation to Research in Zimbabwe

Research on CTM and GRM are important for teachers. It is the researcher's view that training in CTM and GRM will need to be preceded by basic training on active methodologies and the Seven Essential Skills for expanding teacher awareness of the needs of the job market and their students.

With reference to Shulman's 1986 definition of Pedagogical Content Knowledge (PCK), (Kaino 2015), CTM and GRM research indicate that teachers in Zimbabwe would also need training in diagnosing learner's problems and knowledge of alternative ways of representing specific topics. Knowledge of what makes topics difficult or easy – Schulman's model for PCK – would also be essential.

Evaluation in Relation to International Research

Similarities are drawn with teacher attitudes in Portugal and South Africa with particular reference to the transfer of teacher's attitudes to maths onto classroom practice. Both da Ponte and Paulsen comment that teacher's practices are influenced if not determined by their personal views and beliefs about their subjects. Teacher's opinions can be a block to progress in curriculum development (Paulsen 2015; Ponte 1994).

With regard to methodology the comment of one teacher in Portugal indicated the sequential links between curriculum change and methodology change and vice versa: the teacher commented that the new curriculum 'pointed towards a new methodology', acknowledging that prospective new methodologies would involve higher student involvement (Ponte 1994).

Many similarities were noted between responses of teachers in Zimbabwe and teachers in Portugal to curriculum reform and change. In both countries, teachers noted that they would need more preparation time for lessons and would therefore have a greater work load (Ponte 1994). Teachers in Zimbabwe were unaccustomed to group work as were teachers in Portugal (Ponte 1994). Some teachers in Zimbabwe expressed reservations about creating their own materials. In Zimbabwe some teachers disapproved of introducing new topics or topics not normally taught in junior school. The same response was reported in Portugal (Ponte 1994).

In both countries, teachers acknowledged that learners 'enjoyed maths more' (Ponte 1994).

CPD and MKT in both countries could consider well designed workshops to facilitate the neutralisation of teacher's personal views and opinions which encroach on professional development and lifelong training.

CONCLUSION

The study was successful in increasing communication in the class, which in turn increased the performance rate and improved learners' results. The application of CTM and GRM made sessions more lively, enjoyable, memorable and effective with regard to understanding maths through discovery, communication and the use of alternative angles of approach. Group 1 and 3 participants benefited the most from the use of CTM and GRM. They acquired the habit of looking for real life contexts and situations to make sense out of maths.

The instructional style of discovery sometimes entailed a non-linear exploration of topics – often learners experienced more than one topic in a session or a topic beyond the scope of their applicable curriculum, but they gained confidence in their ability to induce maths as well as interest in future curricula. All participants, including those who understood maths easily enjoyed the sessions as each member of the class had a distinct self-affirming function in every session.

The statistics given in this paper can be variable according to the subjects, observers and the conditions in which the testing is affected. However, the study showed that tools and methodologies can aid communication in maths classes.

RECOMMENDATIONS

It is recommended that Communication Tools for Maths CTM and GRM be integrated into primary and secondary schools curricula through pilot programmes. It will be through these programmes that CTM and GRM could be integrated into the Zimbabwe mathematics curriculum. Recommendations to indicate integration of CTM and GRM into MKT and CPD have been made. Furthermore, it is recommended by the researcher and teachers who observed the CTM and GRM sessions that workshops on the Essential Skills be integrated into MKT and CPD.

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