© Kamla-Raj 2015 Int J Edu Sci, 8(1-ii): 223-228 (2015)
PRINT: ISSN 0975-1122 ONLINE: 2456-6322 DOI: 10.31901/24566322.2015/08.01-ii.11

Towards a Framework for Effective Mathematics Continuous Professional Development

Luckson Muganyizi Kaino

Department of Mathematics Education, University of South Africa (UNISA), 169 Ezra Road, Die Wilgers, Pretoria 0184, South Africa
E-mail: kainolm@unisa.ac.za

KEYWORDS Teacher Professional Development.Mathematical Knowledge for Teaching. Mathematics Teaching.Professional Development Frameworks

ABSTRACT This paper surveys various theories and models that have been used in the implementation of mathematics professional development programs in different countries for the past thirty years. The paper also reflects on the ongoing Mathematics Continuous Professional Development (MCPD) project's pilot study findings (reported in another paper of this special issue) that sought for an appropriate MCPD framework for South Africa. The South African study examined the status of existing MCPD practice and the challenges practitioners experienced in the implementation of MCPD programmes. The paper concludes that MCPD models can be categorized into two frameworks that should be considered for effective MCPD programs. These are the Mathematical Knowledge for Teaching (MKT) framework and the Organizational Framework of the MCPD that should also involve evaluation aspects in these frameworks. It is recommended that a framework that develops mathematics teachers and subject specialists in MKT combined with effective organizational structure at district level involving school principals, district officials, service providers and school based professional development activities could suit the current operational structure in the South African education system for effective MCPD.

INTRODUCTION

In the past three decades, studies on teacher professional development are said to consist mainly of documenting teacher satisfaction, attitude change, or commitment to innovation rather than its results or the processes by which it worked (Frechtling et al. 1995; Guskey 2000). Within this period, there has been different mathematics professional development models for in-service teachers intended to improve teacher's knowledge for effective teaching in the classroom. Despite a number of these efforts, teachers' mathematics classroom practices were said to remain largely unchanged because teachers held to their own mathematics understandings, attitudes, and experiences (Ball 1996; Raymond 1997; Tzur 2001). One of the main concerns in professional development programs has been teachers' lack of Pedagogical Content Knowledge (PCK).

PCK has always been related to the quality of teachers in instruction as it enables teachers to make knowledge accessible and understandable to students. Shulman's (1986) theory of PCK was described as the type of knowledge required by teachers, the knowledge of understanding students' ways of thinking, the teacher's ability to diagnose sources of students' errors and knowledge of various alternative ways of representing specific topics (Shulman 1986; Carlsen 1987; Tirosh et al. 1998). PCKwas also described as the knowledge of what made the learning of specific topics easy or difficult and as the knowledge that comprised of subject matter knowledge (SMK) and Pedagogical Knowledge (PK) (Shulman 1987). The PK was described as the general knowledge that the teacher acquired in a methods or professional studies course. PK consists of the learner development theories, learning theories, classroom management, and assessment procedures. Shulman (1986) viewed teacher education as a combination of subject matter and pedagogy for effective preparation of teachers.

Veal and Maknister (1999) described PCK as a way of describing the knowledge possessed by the expert teachers and Tirosh (1999) described it as the method of teaching for understanding. Other researchers such as Grossman (1990), Zeidler et al. (2002), Banks et al. (2005), Wilson and Demetriou (2007) have described PCK as the content knowledge (the knowledge of the subject content that is needed to be taught), general pedagogical knowledge (knowledge of different teaching strategies, classroom management strategies, assessment strategies etc), context knowledge (knowing about the background of the learners, knowing the organizational culture of the school etc.).These developments of Shulman's (1986) PCK typology indicate further need to search for the type of PCK needed by teachers for quality instruction.

Conceptual Frameworks of Mathematics Continuous Professional Development (MCPD)

The development of MCPD programs is mainly concerned with the Mathematical Knowledge for Teaching (MKT) for practising teachers. The conceptual framework for MKT inspired by Schulman's (1986) theory on Pedagogical Content Knowledge (PCK) and developed by Ball et al. (2008), is concerned with the knowledge required for teaching mathematics.MKT was described by Ball et al. (2008) to consist of two broad categories of the Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). Each of these categories was subdivided by Ball et al. (2008) in different domains. SMK was divided into Common Content Knowledge (CCK), Specialized Content Knowledge (SCK) and Horizon Content Knowledge (HCK). PCK was divided into Knowledge of Content and Students (KCS), Knowledge of Content and Curriculum (KCC) and Knowledge of Content and Teaching (KCT). Ball et al. (2008) described CCK as the mathematical knowledge 'used in settings other than teaching' (p. 399), for example recognizing and naming some mathematical shapes or structures. SCK was described as the mathematical knowledge and skill that was 'not typically needed for purposes other than teaching' (Ball et al. 2008: 400) such as adequate knowledge of various definitions of shapes that have to be taught to students at different levels. KCS 'combines knowing about students and knowing about mathematics' (Ball et al. 2008: 401). KCT was described as knowledge of mathematics combined with knowledge of teaching. HCK was described as 'awareness of how mathematical topics are related over the span of mathematics included in the curriculum' (Ball et al. 2008: 403). Jakobsen et al. (2012) argued that HCK included knowledge of the wider discipline of mathematics insofar as its content and practices can inform the work of teaching

Other frameworks for studying teachers' mathematical knowledge have also been proposed. Chick et al. (2006) developed a framework that involved categories that were described as 'clearly PCK'- content knowledge in a pedagogical context and pedagogical knowledge in a content context. Chinnappan and Lawson (2005) developed a framework for studying knowledge of geometry for teaching and applied it to study the knowledge exhibited by two experienced teachers in taped interviews. Heid (2008) analyzed the mathematics needed by teachers from three perspectives: a curriculum-based mathematical thinking approach, a situations approach, and a mathematical process approach. Recently, teacher education research and research on practicing teachers have focused more on the knowledge base of teachers' classroom practice (Blomeke and Delaney 2012).

Kaino and Moalosi (2013) adopted Ma's (1999), Lienhart and Smith's (1985) and Ball's (1990) PCK framework in evaluating teachers' knowledge in teaching linear equations of two variables. The researchers found that teachers lacked Mathematical Knowledge for Teaching (MKT) that comprised of knowledge of the topic content, ways of teaching that content, understanding of students' background of their knowledge in the topic taught and teaching strategies that emphasised application.Ma's (1999) framework required teachers to (1) explain how they taught a particular concept; (2) explain how to perform a particular mathematical task; and (3) explain scenarios where a student comes up with a different way to solve the problem that led to a seemingly correct solution process but misrepresented the correct conception(s). Lienhart and Smith's (1985) framework required the teacher to explain particular mathematical terms, compare and explain the meaning of particular terms, draw and discuss the meaning of a sketch, and to explain problems that students faced in understanding certain concepts. The framework by Ball (1990) used structured multiple-choice items that were posed using various scenarios related to situations that teachers faced in the classroom.

One of the most widely used models in past twenty years or so in developing countries is the cascade model of professional development. The cascade model involved training of experts from the central level to trainees at the local level that is, knowledge to flow down from experts and specialists through several layers of personnel and eventually to the teachers (Dove1986). The model was credited for its ability to train large numbers of teachers quickly and economically (McDevitt 1998; Mpabulungi1999) and/or funding to provide training was limited (Prophet 1995; Gilpin 1997; McDevitt 1998; Hayes 2000; Bax 2002). Despite the said advantages, the cascade model was often criticized. Its main weakness has been the distortion of the messages transferred during the training, passed down through many different levels of personnel. The intended messages are often altered or not properly delivered as intended and their effects have been diluted through miscommunication and different interpretations of the same messages (Mpabulungi 1999).

Another criticism of the cascade model has been the one-way transmission of information where the process is constructed according to a centre-periphery and top-down structure and as such this structure was considered to be too inflexible to respond to the needs at grassroots level (McDevitt 1998). The lack of experience at higher levels, to understand well what was happening in the classroom, could also have made it difficult to predict the needs at the lowest levels. Mezirow (1991) argued that a process of justifying or validating communicated ideas necessary to transfer new ideas which were perceived and comprehended as the top-down approach did not encourage participation and commitment.

In Africa, the deficiencies of the model were observed where the cascade model was implemented. For example, the evaluation study in Botswana revealed that the cascade model failed to be a means of transferring ideas or of changing behaviour because it had little impact on the training programme (McDevitt 1998). As already argued, the cascade model was too inflexible to be able to respond to the challenges from the grass roots level in Botswana (McDevitt 1998; Prophet 1995). The evaluation study of a three-layer cascade model in Uganda revealed problems especially at the lowest level, where trainers did not internalize the messages from their own training and consequently they could not perform well for some steps of the training contents (Mpabulungi 1999).

In South Africa, the cascade model has also been criticized because of its inadequacy to deliver effective training of teachers (Khulisa 1999; HSRC 2000; Graven 2004). The process to disseminate information from top, down to teachers was considered a major problem in training of teachers (Dichaba and Mokhele 2012). The misinterpretation of the information in the process of transmitting to the next level was also observed in previous studies done in South Africa (Fiske and Ladd 2004; Ono and Ferreira 2010). Ono and Ferreira (2010) further observed that teachers in South Africa frequently complained that even the district trainers and subject advisors did not always understand the content and the curriculum when conducting professional development workshops. Despite the ineffectiveness of the use of the cascade model as observed by Graven (2004) for the implementation of Curriculum 2005, this model remained the dominant training model in South Africa (Chisholm 2003). While teachers were offered training through this model, there was little or no follow-up of support structures for teachers who had to deal with the long-term implementation of the new reforms (Robinson 2002).

Apart from the cascade model that has been used in many countries, other models have been tried to address the deficiencies of the cascade model. Of late, the peer mentoring model has been developed as a strategy for provision of professional development to mathematics teachers. This model involving a combination of *one-on-one peer mentoring* integrated with *group peer mentoring* was developed by Kensington-Miller (2013) and experimented to mathematics teachers of senior students. The model which is content-focused, school-based, incorporated into day-today work, collaborative, and teacher-driven is considered inexpensive, easy to set up and could provide relatively immediate access and on-going support, and accommodate the different needs of all the mathematics teachers (Kensington-Miller 2013). The above surveyed frameworks indicate a search for knowledge and skills required by the mathematics teacher for effective teaching.

METHODS OF EVALUATING AND IMPROVING MATHEMATICS CONTINUOUS PROFESSIONAL DEVELOPMENT (MCPD) PROGRAMS

Guskey (2000) argues that learning opportunities for teachers occur every time a lesson is taught, an assessment is administered, a curriculum is reviewed or a professional journal is read. Furthermore, Guskey advocates teacher involvement in development or improvement process for example in designing or choosing a new curricula or textbook or assisting with the school improvement plan. The author suggests an evaluation of a professional development programme at five levels:Level1 Participants' reactions, Level 2: Participants' learning, Level 3: Organizational support and change, Level 4: Participants' use of new knowledge and skills, and Level 5: Student learning outcomes for details see cuskey 2000).

Borko (2004) suggested a conceptual framework that involved the program, facilitators, teachers, and context which map to the quality of professional development. The framework geared to the quality of the program and facilitators, teacher characteristics and knowledge. Pereeini et al. (2004) proposed a conceptual framework that contained complex reflective relationships between teaching practices and teachers' developing knowledge and beliefs about mathematics, mathematics-specific pedagogy and professional identity. The framework includes the knowledge, practice, student learning components and the emphasis on subject-specific content. Desmore (2009) proposed a conceptual framework for studying the effect of professional development on teachers and students. The framework involves testing both the theory on teacher change (that professional development alters teacher knowledge, beliefs or practice) and the theory of instruction **(**that changed practice influences student achievement), both of which were regarded as necessary to complete the understanding of how professional development worked (for details see Wayne et al. 2008). The studies by Carpenter et al. (1989), Franke and Levi (2001), Saxe et al. 2001) had earlier addressed the links in all four areas professional development, content knowledge, instruction and student achievement. The above surveyed literature indicates the dynamic nature of professional development as ongoing, continuous and embedded in teachers' daily lives (Lieberman 1995; Loucks-Horsley et al. 1987).

OBSERVATIONS AND DISCUSSION

The frameworks for mathematics professional development can be classified into two categories. The first category can be classified as an Organizational Framework and the other as the Mathematical Knowledge for Teaching (MKT) framework. The Organizational Framework involves models such as the cascade model that has been widely used in many developing countries for the past 30 years. Many weaknesses of the model have been identified, centring on the distortion and miscommunication of the information from top passed down through many different levels of trainers. The one-way transmission of information where the process was constructed according to a centre-periphery and top-down structure and the lack of experience at higher levels to understand well what was happening in the classroom, contributed to the weaknesses of the cascade model. And as such, the cascade structure was considered to be too inflexible to respond to the needs of the teachers. The other type of Organizational Framework is the *one-on-one peer mentoring* integrated with *group peer mentoring*, advocated by Kensington-Miller (2013) which is said to be content-focused, school-based, incorporated into day-today work, collaborative, and teacher-driven. Such frameworks do not specify which domain of teacher knowledge is targeted or developed in the peer mentoring.

The Mathematical Knowledge for Teaching (MKT) framework involves various models that address the teacher knowledge and effectiveness of teaching. The conceptual framework for MKT inspired by Shulman's (1986) theory on PCK was used to develop different framework components on Common Content Knowledge (CCK), Specialized Content Knowledge (SCK) and Horizon Content Knowledge (HCK), Knowledge of Content and Students (KCS), Knowledge of Content and Curriculum (KCC) and Knowledge of Content and Teaching (KCT). In developing countries, many researches have been done on the Organizational Framework and few on MKT. Borko's (2004) framework on the program, facilitators, teachers, and context which gear to the quality of the professional development program and facilitators, teacher characteristics and knowledge can be considered to be an Organizational Framework that aims at improving the quality of teaching.While Dosmore's (2009) conceptual framework for studying the effect of professional development on teachers and students is an evaluative model for professional development, Guskey's (2000) theory on teacher professional development is both an evaluative and an organizational framework. Other complex frameworks such as that by Pereeini et al. (2004) that involve reflective relationships between teaching practices and teachers' developing knowledge, beliefs and professional identity can be categorized into both organizational and MKT frameworks.

CONCLUSION

This paper has highlighted the background on the various ways used in conducting professional development programmes and the frameworks that have been used. It is concluded from the surveyed literature that frameworks for Mathematics Continuous Professional Development (MCPD) can be categorized into two frameworks that should be considered for effective MCPD programs. These are the Organizational framework and the Mathematical Knowledge for Teaching (MKT) framework. The MKT framework spells out the type of knowledge the teachers should acquire and the Organizational framework comes out as the support for implementation of MCPD.

RECOMMENDATIONS

It is recommended that both the Organizational and the Mathematical Knowledge for Teaching (MKT) frameworks should be used in the development of Mathematics Continuous Professional Development (MCPD). The Organizational framework that combines the development of mathematics teachers and school principals using district officials, subject specialists, service providers and school based professional development activities would suit the South African framework for MCPD.

REFERENCES

Ball DL, Thames MT, Phelps G 2008. Content knowledge for teaching: What makes it so special? *Journal of Teacher Education,* 59(5): 389-407.

Ball DL 1990. The mathematical understandings that prospective teachers bring to teacher education. *Elementary School Journal*, 90(4): 449-466.

Ball DL1996. Teacher learning and the mathematics reforms: What we think we know and what we need to learn. *Phi Delta Kappan*, 77: 500-508.

Banks F, Leach J, Moon B 2005. Extract from new understanding of Teacher's Pedagogical Knowledge. *Curriculum Journal,* 16: 240-331.

Bax S 2002.The social and cultural dimensions of trainer training. *Journal of Education for Teaching,* 28(2): 165-178.

Blomeke S, Delaney S 2012. Assessment of teacher knowledge across countries: A review of the state of research. *ZDM Mathematics Education,* 44: 223–247.

Borko H 2004. Professional Development and Teacher Learning: Mapping the Terrain. Educational Researcher, 33 (8). From <https://openarchive. stanford. edu/sites/default/files/Borko-PD_and_ Teacher_ Learning.pdf> (Retrieved on 15 April 2014).

Carlsen WS 1987. Why Do You Ask? The Effects of Science Teacher Subject-matter Knowledge on Teacher Questioning and Classroom Discourse. *Paper Presented at the Annual Meeting of the American Educational Research Association,* Washington, DC.

Carpenter TP, Fennema E, Peterson PL, Chiang C, Loef M 1989. Using knowledge of children's mathematics thinking in class room teaching: An experimental study. *American Educational Research Journal,* 26(4): 499-531.

Chinnappan M, Lawson MJ 2005. A framework for analysis of teachers' geometric content knowledge and geometric knowledge for teaching. *Journal of Mathematics Teacher Education,* 8: 197–221.

Chick HL, Pham T, Baker MK 2006. Probing teachers' pedagogical content knowledge: Lessons from the case of the subtraction algorithm. In: P Grootenboer, R Zevenbergen, M Chinnappan (Eds.): Identities, Cultures and Learning Spaces. *Proceedings of the 29th Annual Conference of the Mathematics Education Research Group of Australasia.* Canberra: MERGA, pp. 139-146.

Chisholm L 2003. The Politics of Curriculum Review and Revision in South Africa. *Presented at the Oxford International Conference on Education and Development, 9-11 September 2003, at the session on Culture, Context and the Quality of Education.*

Desmore LM 2009. Improving impact studies of teacher's professional development: Toward better conceptualizations and measures. *Education and Educational Research,* 38(3): 181-199.

Dichaba MM, Mokhele ML 2012. Does the Cascade Model Work for teacher training? Analysis of teachers' experiences.*International Journal of Educational Sciences (IJES),* 4(3): 249-254.

Dove LA 1986. *Teachers and Teacher Education in Developing Countries*. New Hampshire: Croom Helm.

Fiske EB, Ladd HF 2004. *Elusive Equity: Education Reform in Post-apartheid South Africa.*Washington: DC: Brookings Institute.

Franke ML, Carpenter TP, Levi L 2001. Capturing teachers' generative change: A follow-up study of professional development in mathematics. *American Educational Research Journal*, 38: 653-689.

Frechtling J, Sharp L, Carey N, Vaden-Kiernan N 1995. *Teacher Enhancement Programs: A Perspective on the Last Four Decades*. Arlington, VA: National Science Foundation, Directorate for Education and Human Resources.

Gilpin A 1997.*Cascade Training: Sustainability or Dilution? In Learning to Train: Perspectives on the Development of Language Teacher Trainers*. Hemel Hempstead: Prentice Hall.

Graven M 2004. Investigating Mathematics teacher learning within an in-service community of practice. *The Centrality of Confidence Educational Studies in Mathematics*, 57(2): 177-211.

Grossman PL 1990. *The Making of a Teacher: Teacher Knowledge and Teacher Education*.New York: Teachers College Press.

Guskey TR 2000. *Evaluating Professional Development.* Thousand Oaks, CA: Corwin Press.

Hayes D 2000. Cascade training and teachers' professional development. *English Language Teaching Journal*, 54(2): 135-145.

Human Science Research Council 2000. *Formative Evaluation and Monitoring of Curriculum 2005 Implementation in Gauteng: Preliminary Report Submitted to Gauteng Institute for Curriculum Development.*Pretoria: Human Science Research.

Jakobsen A, Thames MH, Ribeiro CM, Delaney S 2012. Using practice to Define and Distinguish Horizon Content Knowledge. *Paper prepared for the twelfth International Conference on Mathematical Education.* Seoul, Korea.

Kaino LM, Moalosi S 2013. Teachers' mathematical pedagogical content knowledge: Some trends in search of adequate knowledge for effective teaching. *Journal of Social Sciences (JSS*), 37(1): 189-196.

Kensington-Miller B 2013. Professional Development for Secondary School Mathematics Teachers: A Peer Mentoring Model. From <http://www.cimt. plymouth. ac.uk/journal/kensington-miller.pdf> (Retrieved on 24 August 2013).

Khulisa Management Services 1999. *Evaluation of OBE/C2005 in Gauteng Province.* Gauteng Department of Education/ Gauteng Institute of Curriculum Development. Johannesburg: Global Print.

Lieberman A 1995. Restructuring schools: The dynamics of changing practice, structure, and culture. In: A Lieberman (Ed.): *The Work of Restructuring Schools: Building from the Ground Up.* New York: Teachers College Press, pp. 1-17.

Leinhardt G, Smith DA 1985. Expertise in mathematics instruction: Subject matter knowledge. *Journal of Educational Psychology*, 77(3): 247-271.

Loucks-Horsley S, Harding C, Arbuckle M, Murray L, Dubea C, Williams M 1987.*Continuing to Learn: A Guidebook for Teacher Development*.Andover, MA and Oxford, OH.

Ma L 1999.*Knowing and Teaching Elementary Mathematics*: *Teachers' Understanding of Fundamental Mathematics in China and the United States.* Mahwah, NJ:Lawrence Erlbaum Associates.

McDevitt D 1998. How effective is the cascade as a method for disseminating ideas? A case study in Botswana. *International Journal of Educational Development,*18: 425-428.

Mezirow J 1991. *Transformative Dimensions of Adult Learning.* San Francisco: Jossey-Bass Publishers.

Mpabulungi A 1999. *Assessment of the Cascade Training*. *UNCDF on Learning and Teaching Mathematics: Implications for Teacher Development*. Uganda Working Brief Series, Kampala, Uganda.

Ono Y, Ferreira J 2010. A case study of continuing teacher professional development through lesson study in South Africa. *South African Journal of Education*, 30: 59-74.

Peressini D, Borko H, Romagnano L, Knuth E, Willis C 2004. A conceptual framework for learning to teach secondary mathematics: A situative perspective. *Educational Studies in Mathematics,* 56(1): 67-96.

Prophet R 1995. View from the Botswana Junior Secondary classroom: Case study of a curriculum intervention. *International Journal of Educational Development*, 15(2): 127-140.

Raymond AM 1997. Inconsistency between a beginning elementary school teacher's mathematics beliefs and teaching practice. *Journal for Research in Mathematics Education*, 28(5): 550-576.

Robinson M 2002. Teacher reforms in South Africa: Challenges, strategies and debates. *Prospects Journal*, 11(3): 289-299.

Saxe GB, Gearhart M, Nasir NS 2001. Enhancing students' understanding of mathematics: A study of three contrasting approaches to professional support. *Journal of Mathematics Teacher Education*, 4: 55-79.

Shulman LS 1987. Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1): 1-22.

Shulman LS 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2): 4-14.

Tirosh D 1999. Enhancing teachers' knowledge of children's conceptions: The case of division of Fractions. *Journal for Research in Mathematics Education*, 22: 125-147.

Tirosh D, Even R, Robinson N 1998. Simplifying algebraic expressions: Teacher awareness and teaching approaches. *Educational Studies in Mathematics*, 35:51-64.

Tsur R, Simon MA, Heinz K, Kinzel M 2001. An account of a teacher's perspective on learning and teaching mathematics: Implications for teacher development. *Journal of Mathematics Teacher Education*, 4, 227-254.

Veal WR, Maknister JG 1999. Pedagogical Content Knowledge Taxonomies. From <http://unr.edu/homepage/crowther/ejese/vealmak.html> (Retrieved on 23 August 2005).

Wilson E, Demetriou H 2007. New Teacher Learning; Substantive Knowledge and Contextual Factors. From <http://www.educ.cam.ac.uk/people/staff/wilson> (Retrieved on 12 June 2012).

Zeidler DL, Walker KA, Ackett WA, Simmons ML 2002. Tangled up in views: Beliefs in the nature of science and responses to socio-scientific dilemmas. *Science Education,* 86(3): 343-367.