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Mentoring for Developing Teachers' Specialised Knowledge of Mathematics Pre-Service Teachers at the Intermediate Phase

John Elphas Masina; Msawenkosi Sandile Mbokazi

Department of Education Professional Practice, Faculty of Education, University of Zululand, Kwa Dlangezwa, South Africa

Corresponding Author: Msawenkosi Sandile Mbokazi; msmbokazi@gmail.com

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Abstract

This study was conducted to explore the link between mentoring of intermediate phase pre-service teachers of mathematics and the development of mathematics teachers' specialised knowledge (MTSK). The focus is on how the teaching practice (TP) program (Practicum) provides an opportunity for the development of mathematical teachers' specialised knowledge (MSTK) for pre-service teachers. The qualitative research approach was employed for data collection and then analysed through the thematic narrative analysis technique and categorised into MTSK sub-domains. Data revealed that mathematics mentors, in the intermediate phases, did not attempt to develop pre-service teachers' mathematical teacher's specialised knowledge (MTSK), thus negatively impacting building a comprehensive conceptual framework of effective Mathematics teaching practice. Data also revealed that the mathematics mentors are not mathematics specialists; they lack mathematical specialised content knowledge (MSCK) and mathematics pedagogical content knowledge (MPCK). The study recommends that mathematics mentoring be based on mathematics specialisation; that is, teachers who majored in mathematics strictly should be mathematics mentors. Further, they should be competent and possess mathematical expertise, commitment, and time to assist pre-service mathematics teachers during practicum. The development of MTSK and its approaches and techniques for mathematics teaching and learning should also be emphasised during the mentoring process.

Keywords: *Teaching Practice; Mentoring Process; Student Teachers; Mathematics; Knowledge; Pedagogy; Pre-Service Teachers*

Introduction

In all teacher education, teaching practicum, also known as school experience, is a significant component of teacher education programmes' curricula (Msimango, Fonseca & Peterson, 2020). Teaching practice or practicum becomes a bedrock on which teachers integrate theoretical learning from university coursework with practical experience (Gravatt & Ramsaroop, 2015). Student teachers are envisaged to apply mathematical knowledge, strategies, and skills in an unfamiliar and new environment. Such environments are theoretical explained at their institution and without practically experiencing them.

Furthermore, there is a belief that research should concentrate on the transference of mathematical knowledge and skills from university to real mathematics situations (Modipane & Kibirige, 2015). It is, basically, essential for student teachers of mathematics in teacher education to pass through practicum as the component of their curriculum. It enables them to comprehend different environments of teaching and learning mathematics. According to Raybould & Sheedy (2005), Ensor, (2014) & Modipane & Kibirige (2015), the practicum helps students to experience different environments of mathematics teaching and learning. Should they fail, this may negatively impact their employability due to failing to illustrate their mathematical knowledge and skills at school. Furthermore, researchers assert that mentoring is a valuable process in developing both mathematical teachers' specialised knowledge (MTSK) and skills. Additionally, mathematics pedagogical content

knowledge (MPCK) assists in imparting this knowledge and skills (Ganser, 1996), supporting student teachers during the practicum process, and contributing to the development of both mathematics content knowledge (MSCK) and MTSK. Since the "Equality of Educational Opportunity" study by Coleman (1966), researchers have established a distinct endowment of teacher mathematical specialised knowledge to learners' performance in mathematics (Hill, Blunk, Charalambous, Lewis, Phelps, Sleeps & Ball, 2000). Borko, Eistenhart, Brown, Underhill, Jones & Agard (1992) asserted that teachers' MTSK also impacts instruction. Several studies revealed the significance of the quality of learning opportunities and teaching practice experiences in raising pre-service teachers' MTSK and MPCK (Ferretti, 2022). According to predictions based on profession-specific knowledge and mathematical common content knowledge (MCCK), Mathematics Teachers' Specialised Knowledge (MTSK is not acquired incidentally but rather through academic study, mentoring during practice teaching, and reflection on classroom experiences (Ball, Lubienski & Mewborn, 2001 and Grossman, 2008). On the other hand, research conducted by Lee et al. (2007); Kleickmann et al. (2013), & Hurrell (2013) confirm that student teachers possess a limited repertoire of both mathematics teachers' specialised knowledge and mathematical common content knowledge. The authors posit that mentoring experience fundamentally influences the acquisition, shaping, and development of a student teacher's mathematical teachers' specialised knowledge and mathematical common content knowledge.

South African universities providing teacher education embraced the importance of mentoring during student teachers' practicum. As awareness continues to focus on student teachers as the key factor in teaching practice and their need for ongoing development, improvement and support, mentoring in mathematics becomes a viable opinion in teacher education policy (Ball, 2008). Without this focus on mentoring mathematics student teachers, such practicum efforts will eventually fail, specific in the development of mathematics student teachers' mathematical teachers' specialized knowledge (MTSK) in the intermediate phases must provide mathematical support, advice, empathy and role modelling to mathematical student teachers, during practice teaching (Hall et al., 2008This study is based on the claim that mentoring during practicum, and more specifically in the development of pre-service teachers' MTSK for mathematics content knowledge for teaching, is an extremely important aspect of teaching practise as the primary component of teachers' curriculum (Msimango, Fonseca & Peterson, 2020). In contrast, a practical teaching practice experience is based on both mentor's expertise and a conducive mentoring environment and minimising mentoring hindrances (Modipane, Kibirige, 2015, Graham, 2006). The researchers agree with the perception that mathematics mentor teachers provide development of MTSK of the mathematics student teachers, shape their mathematics teaching practice and play a critical influence in determining the type of mathematics teacher that students will become (Hudson & Hudson, 2011, Rhoad, Radu & Weber, 2011). We aspire to examine the mentoring practices of teachers in the rural school settings at King Cetshwayo District. Mentors are appointed and trained to assist mathematics student teachers by utilising their specialised mathematics knowledge, which is pure mathematics and specific to the profession, for example teaching profession (Flores, Escudero & Carrillo,2013). They also use specific models to develop numerical concepts (Msimango, Fonseca & Peterson,2020). In our view, mentoring is informed by the mathematical specialised knowledge of student teachers and mentors.

Conceptualisation of Specialised Knowledge for Mentoring

Shulman (1987) in the mid-1980s, introduced subject knowledge for teaching and developed a model that emphasised the knowledge areas that teachers need to acquire, known as pedagogical content knowledge (PCK) (Ferretti, 2020). Following years later, several studies sparked by Shulman ideas deliberated new ideas based on both content knowledge and the way it is taught (Depaepe et al., 2013). These studies aimed to investigate the knowledge of teachers and specifically concentrated on empirical methodologies for understanding the mathematical knowledge needed for teaching by analysing its basis, function, and relevance (Ferreti,2020). They also helped to improve PCK by identifying subdomains and gave a framework for conceptualising the information and mathematical abilities required for teaching by identifying specialised content knowledge (SCK) (Ngcobo-Ndlovu, Amin & Anthony Samuel,2017). Carrillo-Yanez et al. (2018), on the other hand, state that the MKT model's goal of the study is the investigation of mathematical knowledge used by teachers to teach, rather than their overall knowledge, with an "emphasis on classroom teaching and learning" (Ball et al., 2008). Numerous research has been conducted on the MKT model of student teachers during practicum. However, they ignored the role of MTSK developed by mathematics mentors for mathematics student teachers during practicum, as well as the role of mentoring in the development of MTSK among intermediate mathematics student teachers. According to the affective domain study (Leder Forgaz, 2006), the MTSK model takes into account both perspectives on mathematics as well as its teaching and learning, which is critical to the model's emphasis on belief and knowledge domain reciprocity (Carrillo-Yanez et al., 2018). Mentoring mathematics is a complex and challenging habit for primary school teachers to be generalists. Some mentor teachers may lack sufficient content knowledge, skills, specialised knowledge, or confidence to teach at the primary level, especially in mathematics. As a result, student teachers may not receive equitable mentoring to improve their mathematics teachers' specialized knowledge (MTSK) (Hudson, 2006, Msimango, Fonseca & Peterson, 2020). Pre- and post-lesson discussions with the mentor, showing a lack of attention to the development of MTSK are challenging. In this study, we classified the MTSK model based on its distinct sub-domains as per Carrillo-Yáñez et al. (2018).

MTSP category MTSK	Evident when student-teacher…..
KOT	Declared on the increase in their KOT Increasing understanding of fundamental concepts and spatial numerical systems. Analysing numerical, numbering systems and representation of numbers.
KSM	Understanding of the relationships between different mathematical objects. Temporal consideration relates to mathematics and sequencing regarding complexity or simplification.
KPM	Works on mathematical than the process of teaching it. Focuses on production methods and mathematical operations. Meta-cognitive reflection on positional and decimal system principles, as well as beliefs about future mathematical activities.
MTSK and PCK: Teaching and Learning.	
KFLM	Learns about the problems that their students would have when learning

	the fundamental topics. Aware that place value concepts are a general difficulty among intermediate phase learners.
KMT	Comprehension of the possibilities of specific mathematical subject teaching activities, methodologies, and techniques Beliefs in planning activities, techniques, and tools for future teaching methods
MLS	Understands Mathematical Knowledge found in official documentation, like national Mathematical Curriculum Guidelines, CAPS documents, ATPs and Mathematics Policy Documents, SACE and UMALUSI, NDBE

Table 1: MTSK (adapted from Carrillo-Yáñez, et al. 2018)

Many studies of interactions between mathematics mentors and mathematics student teachers have found that when mathematics teachers' mentoring practices are centred on a mutual relationship (Hudson & Hudson, 2011), mathematics student teachers' MTSK develops. Wolf (2003) discovered, for example, that a mathematics student teacher got a richer conceptual understanding of mathematics through a lesson plan conversation with his mentor. The development of the mathematics student teachers' MTSK enabled them to increase their knowledge of fundamental ideas, consider mathematics complexity and simplification, work on mathematics rather than teach it, and be aware of the possibility of future activities, methods, and tools.

The current research aimed to examine the mentoring role in developing MTSK among mathematics student teachers in the intermediate phase during practice teaching**.**

Methodology

The study is located in the interpretive paradigm and adopted a qualitative research design (Creswell, 2009). The case study was adopted to highlight the role of mentoring in the development of mathematics teachers' specialised knowledge (MTSK) among student teachers during teaching practice (TP). The sample comprised fifteen (15) mathematics pre-service teachers purposively selected from the mathematics, sciences and technology education stream. Mathematics student teachers (MST) were placed in different schools during teaching practice to improve and develop mathematics teachers' specialised knowledge (MTSK) for teaching. We employed both semi-structured interviews and focus group interviews to answer our research questions. Galvin, (2014) proposes that 7-8 interviews are sufficient for descriptive studies with less than 20 participants. Whereas Hagaman & Wutich, (2016) suggest that 3 interviews are sufficient and warm that not more than 16 interviews at the site level. Therefore, the study comprised three (3) interview sessions with five (5) participants in each session. Furthermore, the interview sessions were tape-recorded, and field notes capture through observations during the interviews.

Data Analysis

Data from interviews were thematically analysed to identify key ideas that emerged. Data was transcribed through open, axial, and selective coding methods (Flick, 2006, De Vos, 2010). Transcripts were read repeatedly during open coding to develop critical ideas. Key concepts from open coding are reorganised to generate sub-themes during axial coding. During selective coding, sub-themes from interviews were cross-checked against the study's aim to inform emergent themes or core categories. The process of identifying, clustering, analysing and giving meaning to essential and relevant statements to the research was repeated to ensure that no critical information was omitted. After analysing and interpreting every theme, findings were made and discussed. The responses were then aligned and categorised to the MTSK model's subdomains as speculated by Carrillo-Yanez et al. (2018).

Findings

Findings about pre-service mathematics' specialised knowledge were analysed and aligned to Carrillo-Yáñez's (2018) domains and subdomains.

Knowledge of Topics (KOT)

Most student-teachers responses indicated that there is no development or improvement in their KOT. The majority of student teachers indicated that the mentoring process in teaching practice did not help them strengthen their understanding of fundamental principles and positioning numerical systems. They indicated that there were no changes after the mentoring process; there were no changes in terms of KOT. Very few revealed an increase in their KOT.

Some preservice teachers had the following to say:

> *No, the mentoring process failed to develop my KOT because my mathematical mentor did not major in mathematics at the Tertiary level. He last studied mathematics in Grade 12, and he lacks in-depth knowledge of mathematics* (S1).
>
> *Yes, my mentor is a mathematician with a master's degree in maths. He did not only help me to teach Maths but also taught me the concept of a positive longing numerical system* (S15).
>
> *My mentor lacked basic knowledge of mathematics*, (S3).
> The above statements were confirmed by the confession of some mentors that mathematics is not their major or choice subject but was forced to teach it.
>
> I *was not good at mathematics, and I did not like it, since it was giving me hard time. As a result, I did not specialise in math, the principal begged me to accept the package since very few teachers were willing to teach mathematics (M1)*

Knowledge of Structure of Mathematics (KSM)

Most student teachers indicated that the mentoring process did not develop their understanding of the relationships between various mathematical items. However, very few declared that the mentoring process assisted them in increasing their knowledge of the structure of mathematics (KSM).

> *Practice teaching had less or minimal impact in terms of developing our KSM* (S6, S7, S8).
>
> *As I stated that my mathematics mentor is a mathematician, and he developed my KSM, and now I think I am thinking great about zero and its importance* (S15).
>
> *I ensure that student teachers under my supervision understand relationships between various mathematical items as a result increase their Knowledge of the Structure of Mathematics M3).*

Knowledge of Practices in Mathematics (KPM)

Student teacher participants had no classroom experience, so they thought only about beliefs about their future practices. Most student teachers felt that the failure of their mathematics mentors to develop KPM would harm future practices. In contrast to the teaching approach, KPM concentrated on the operation of mathematics (Ferretti, 2020). It is related to mathematical meta-knowledge and is also concerned with means of production and functioning (Carrillo-Yáñez, et al. 2018).

The failure of my mentor to develop my KPM would affect me in the future as a teacher. (S10).

Mastery of KPM, taught by my mentor, will assist me in my future maths teaching practices (S13).

Knowledge of Features of Learning Mathematics (KFLM)

According to Ferretti (2020), KFLM is related to mathematical learning features and focuses on mathematical content as the objective of learning. The research revealed that mathematics mentors' lack of specialised knowledge has hampered students' access to understanding the challenges that learners will face when studying the basic concepts, positional and decimal systems, and numbering systems.

Being under Mr Nkosi as my mathematics mentor helped me realise that my students would struggle to understand the numbering system (S15).

It emerged that very few pre-service teachers gained KFLM during the mentoring process.

Knowledge of Mathematics Teaching (KMT)

The KMT sub-domain focuses on framing knowledge that is intrinsically linked to content while ignoring components of generic pedagogical knowledge (Carrillo-Yanez et al., 2018). KMT entails being aware of the activities, strategies, approaches, and skills required to teach SMCK. The majority of students indicated that in some schools, they often found a contradiction between what they are taught at the university and what they are expected to implement during practicum. For instance, S1, S2, and S5 agreed that their mathematics mentors did not prepare mathematics lessons accordingly. They simply wrote in notebooks or diaries and the learning outcomes, assessment standards, skills, knowledge, attitudes, and values (SKAVs) were not incorporated. Others, (S11, S12, S13, S15) on the other hand, stated that their mentors helped them progress, specifically in several KMT elements such as creating activities, presenting the decimal system, and that activities are highly useful for the process of teaching and learning basic positional concepts. They confirmed that they will consider them when they teach.

Practice teaching assisted me in testing the knowledge of our positional system, I will use them when I want to reinforce the concepts of our positional system."

Knowledge of Mathematics Learning Standards (KMLS)

The KMLS entails knowing which mathematics topics need to be taught at any practicum level. These topics are found in curriculum documents (Ferretti, 2020) including National Curriculum Statements Grades R-12, CAPS documents for each subject, National Policy documents for the programmes and promotion requirements, and Subject Guidelines (National Department of Basic Education, 2012). Some student teachers stated that TP made them aware that developing a good attitude about mathematics is one of the goals of mathematics.

Thanks to the teaching practice, I found that the policy documents for mathematics Grades 4-6 explicitly need us as student teachers to look at mathematics approaches other than our own (S15).

The respondents furthermore mentioned that teaching practice assists them in developing a positive attitude towards mathematics and its national objectives.

Discussion and Conclusion

The study investigated how mentoring provided the opportunity for developing mathematical specialised knowledge to pre-service mathematics teachers during teaching practice. The data were analysed within the MTSK model of Carrillo-Yáñez et al., (2018). Data revealed no evidence of MK aspects being developed by mathematics mentors among mathematics student teachers and very few showed the MK aspects. This indicates that Mathematics knowledge is needed by student teachers, which can be located in MK sub-domains (Carrillo-Yáñez et al., 2018). In this instance, mathematics mentors should have used the MTSK model for mentoring needs of their mathematics mentees. In contrast, the mathematics specialised knowledge of one of the mentors assisted at least one mathematics student teacher in the development of MK sub-domains. It also manifested that all the mentors lacked knowledge of aspects of KOT, KSM, KPM, MK, PCK, KFLM, KMT, and KMLS.

A lack of mathematics specialized knowledge (MSK) harmed the growth of student teachers' KFLM, KMT, and KMLS throughout teaching practice processes. The mathematics mentor teachers had just a cursory comprehension of the mathematics specialised context knowledge recognised (Ferretti, 2002) as critical for the development of student teachers' MK and MPCK. The University of Zululand's mentorship training was essentially inadequate, if not defective, and insufficiently focused on the development of mathematics expertise in terms of tactics and approaches for teaching specific mathematical topics. Mathematics teachers with in-depth knowledge of mathematics in primary schools display a conceptual understanding that extends beyond the "what" to the "how" and "why" of mathematical concepts, and they are well-positioned to connect mathematical concepts and topics (Msimango, Fonseca and Peterson, 2020; and Luping, 1999). Pre-service teachers can create balanced mental models of successful teaching by witnessing good mathematics teaching practises (Collins et al.,1991). Due to mentoring received, pre-service teachers constructed and developed only fragmented knowledge (MK & MPCK), exposing discrepancies between what their teachers encouraged them to do and what they performed. Pre-service teachers developed conceptual models of "what to teach" rather than "how and why to teach" mathematical knowledge. The data obtained indicated that mathematics mentors lacked knowledge and inexperience. They lacked experience in developing effective mentorship programmes for student teachers that focused on the development of both MTSK, disciplinary knowledge, and MPCK. Instead of focusing on student teachers' progress and developing both Mathematics Specialized Knowledge for teaching and MPCK, the mentors concentrated on their compliance with content and working towards curriculum coverage. Furthermore, it was evident that pre-service teachers' MSK and PCK were overlooked, which confused the researchers. The Curriculum and Assessment Policy Statements (CAPS) emphasise MTSK as well as the knowledge, abilities, and strategies of teaching mathematics at the intermediate phase. In short, almost all mathematics mentors anticipated a lack of MK in sub-domains such as KOT, KSM, KPM, KMT, KFLM, KMLS and KFLM as defined by the MTSK framework. However, it was not expressly stated that the mathematics mentor teacher supported them in understanding how students think when confronted with mathematical activities and assignments, nor did they express any awareness of the mathematics teacher that the students have issues with a certain topic. Articulation is one of six mentoring practises (Collin et al., 1991; Msimango, Fonseca, & Peterson, 2020) that refers to the ability of mathematics mentor teachers to explain their mathematical knowledge and reasoning of the many aspects of MTSK referred to by the

PCK and KFLM. The teacher's overall understanding of the subject matter and familiarity with the students feed the awareness, as do knowledge of common subjects (KCS) theories and their significance in how learners learn mathematics and what these perspectives contribute to the description of the mathematics learning process. It refers to the subject knowledge and student theories, whereas KFLM is concerned with how mathematics is taught, i.e. defining the features of mathematics learning (Carrillo-Yáñez et al., 2018). However, the ability to do so regarding KCS theories and KFLM should not be limited to mathematics mentors. Student teachers should be provided opportunities to demonstrate their KCS understanding explicitly. As a result, student teachers were unable to use the autonomy they had gained during the previous two years. Further, Knowledge of Mathematics (KMT) excludes general pedagogical knowledge (Carrillo-Yáñez et al., 2018). It is rather a "knowledge which allows mathematical teachers to select a particular representation or certain material for learning a concept or mathematical procedure and which allows them to select examples or choose a textbook" (Carrillo-Yáñez et al., 2018). This knowledge entails being aware of the potential of activities, strategies, and techniques for teaching particular mathematical content as well as knowing how to approach a structured series of examples to help students comprehend the meaning of mathematical terms. Student teachers' autonomy is the freedom they have to make their own decisions while selecting cognate demanding activities, learning materials, strategies and approaches (Tehrani & Masor, 2012). Msimango emphasised that teaching practice means to experiment, reflect on learning, and regenerate their knowledge of teaching and learning, not imitate the knowledge practice of others (Msimango, Fonseca & Peterson, 2020). This implies that student teachers should be exposed to and engage in diverse teaching knowledge explorations under the supervision and direction of a mathematics mentor. Additionally, KLMS addresses the understanding of mathematical curriculum, and progression requirements, nation learner teacher support material programmes, assessment standards and forms of assessment, Carrillo-Yáñez et al., 2018). It also includes national mathematics objectives and performance indicators created by regulatory institutions such as the board of examinations like Umalusi, teacher professional organisations and SACE as external agencies for assessment and evaluation. The KMLS is not mathematical knowledge, however, it is a requisite, and it also does not include mathematics pedagogic knowledge. It includes the knowledge of mathematics curricular specifications, National Progression Requirement and Guidelines on mathematical objectives and standards. However, the findings suggest that student teachers were not exposed to such type of knowledge due to poor mentoring training programmes. Since it was flawed, non-existent and inadequately captivated by mathematical knowledge (MK) and mathematics teachers' specialized knowledge (MTSK). It concentrated on mathematics mentor teachers, but since the teachers couldn't create cognitive apprenticeships with student teachers, the researchers began to wonder if the mathematics mentor teachers had a thorough knowledge and understanding of mathematics intrinsically. The researchers were also concerned specifically about the mathematics illiteracy of mentor teachers and such deficit of this in the intermediate phase. If mathematics mentor teachers lack in-depth MTSK and MK for the mentoring process, mathematics teacher education programmes would perpetuate inadequate mathematics teaching in South African primary schools.

The University is in charge of ensuring that mathematics mentor teachers are appropriately prepared to engage with student teachers during TP. They must have been selected based on their mathematical knowledge of teaching (MKT), specialized content knowledge (SCK), common content knowledge (CCK), horizon content knowledge (HCK), and knowledge of content and teaching (KCT) within pedagogical content knowledge (PCK) in mathematics as a discipline, as advocated by Shulman (1987) model. This expertise, particularly mathematics teachers' specialized knowledge (MTSK), is essential to ensure that mathematics mentorship programmes focus on the development of subject-specific knowledge processes. Not only would the mentor teacher build mentoring techniques, but also a deep knowledge and comprehension of mathematics and mentors' mathematics teaching approaches. Furthermore, well-structured mathematics mentoring programmes must include collaboration between the University of Zululand and schools, as well as developmental and coaching relationships between mathematics mentor teachers and teacher educators, as well as strong mentorship between mathematics mentors and mathematics student teachers (Msimango et al., 2020 & Cheng, Cheng & Tang, 2010). There are guidelines and standards for teaching and evaluation. This set of norms and criteria, as well as appropriate mathematical mentor capacity, will alleviate inconsistent and confusing mentoring procedures. Therefore, mathematics mentorship strategies will help student teachers acquire MTSK during classroom practice.

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