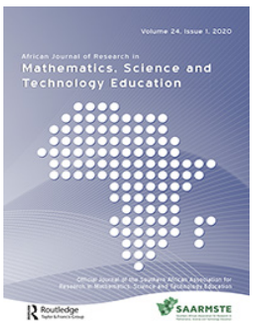

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Mathematical Knowledge for Teaching: How do Primary Pre-service Teachers in Malawi Understand it?

Everton Lacerda Jacinto *, and Arne Jakobsen

Faculty of Arts and Education, University of Stavanger, Stavanger, Norway
**Corresponding author. Email: everton.l.jacinto@uis.no; University i Stavanger, Kitty Kiellands hus, Rennebergstien 30, 4021 Stavanger, Norway*

While a consensus within the field exists that pre-service teachers need adequate knowledge and skills to become effective teachers in mathematics, less is known about how they understand the mathematical knowledge needed for teaching in elementary education. This paper explores how Malawian pre-service teachers understand the mathematical knowledge needed for teaching in primary schools. Written answers to a questionnaire survey, and data from six individual interviews collected at the beginning of the teacher-training programme will be presented. The analytical framework is based on the practice-based theory of mathematical knowledge for teaching, with a specific focus on the domains of the common, horizon and specialised content knowledge. The data revealed that, while taking theoretical courses, pre-service teaches develop only intuitive but complementary views of what is proposed by the theory, which is even the case with pre-service teachers with some prior teaching experience. Findings provide insights into the development of pre-service teachers' mathematical knowledge for teaching, and suggest that further research is needed on how pre-service teachers articulate their understanding of teaching in practice.

Keywords: *Malawian teacher training; primary school education; mathematical knowledge for teaching*

Introduction

In recent decades, some progress has been made in achieving global targets in education. However, there are significant gaps in the quality of teaching and learning in low-income countries, especially in the sub-Saharan region (Altinyelken, 2010; UNESCO, 2016). The Republic of Malawi—one of the first sub-Saharan countries to implement free primary education (Wanda & Mgomezulu, 2014)—has updated their teacher training curriculum to better prepare pre-service teachers for the challenges of teaching all subjects. In the field of mathematics, a recent study conducted at eight primary pre-service teacher colleges in Malawi showed a statistically significant increase in the pre-service teachers' mathematical knowledge for teaching during their training (Jakobsen et al., 2018). However, the overall change in mathematical knowledge for teaching was relatively small, and most pre-service teachers' mathematical knowledge for teaching showed little improvement during teacher training at their teacher-training college.

While the study of Jakobsen et al. (2018) looked at quantitative changes in pre-service teachers' mathematical knowledge for teaching during teachers' first year at teacher-training college, there is still little knowledge about what beginner teachers think and experience in their teacher-training programme. Thus, the present study aims to gain a better understanding of how pre-service teachers in Malawi understand the mathematical knowledge needed to

handle the tasks of teaching in primary schools. The main question is: *How do Malawian pre-service teachers understand the mathematical knowledge for teaching in primary schools?* By mathematical knowledge for teaching, we refer to the 'mathematical knowledge that teachers need to carry out their work as teachers of mathematics' (Ball et al., 2008, p. 4), which is grounded in Shulman and Sykes's (1986) definition of the knowledge base for teaching, which they describe as 'the body of understanding and skills, and device and values, character and performance that together constitute the ability of a teacher to teach mathematics' (as cited in Fernandez, 2014, p. 82).

Framing Teachers' Knowledge within the Malawian Context

There has been a significant increase in international research focusing on teachers' learning (Castle, 2013; Cochran-Smith, 2004; Darling-Hammond & Bransford, 2005; Putnam & Borko, 1997) and on different forms of knowledge needed to prepare pre-service teachers for their future profession (Cheng et al., 2014; Rowland & Turner, 2007). In the USA and in some countries in Europe and Latin America, teacher-training programmes have in many ways advanced in these fields (Darling-Hammond, 2006; Fernández-Soria, 2013; Ries et al., 2016). These programmes have established guidelines that have contributed to the design of new educational policies, models for teaching training programmes and school curricula to assist teachers in responding to the problems arising in school. In contrast, although Asian and African countries have also presented some improvements in those areas, few studies have been conducted in these regions on pre-service teachers' learning and experiences during teacher education (Depaepe et al., 2013).

In the sub-Saharan African region, recent reform efforts have focused on teachers' mathematical knowledge as the answer to several challenges in teaching and teacher education (UNESCO, 2016). In Malawi, the Ministry of Education recently implemented a new curriculum to improve initial primary teacher education. The document specifies that the main function of teacher training colleges should be to prepare future teachers to acquire the right knowledge, skills and competencies so that they can face the challenges in this context (Malawian Institute of Education, 2017). Most of the theoretical background behind this document is based on Shulman's (1986) ideas about subject matter knowledge, pedagogical content knowledge and curricular knowledge (Malawian Institute of Education, 2017).

Although Shulman's (1986) theory outlines a knowledge base needed for effective teaching, this study relies on the practice-based theory of mathematical knowledge for teaching (MKT) developed by Ball et al. (2008). Based on Shulman's (1986) ideas, Ball et al. (2008) count on a specific conception of teaching that emphasises teachers' abilities to transform subject matter knowledge into pedagogical methods to improve students' learning (Ball & Bass, 2000). Since the focus is on shaping and refining the knowledge and skills needed to conduct teaching effectively, not only does MKT help teachers and pre-service teachers to develop decision-making skills essential for teaching certain topics in the classroom (Johnson, 2009), but it also provides a sustainable theoretical base and practical implications for teacher education programmes (Hill et al., 2005).

The theory of MKT encompasses the following six teachers' knowledge domains: common content knowledge (CCK), horizon content knowledge (HCK), specialised content knowledge (SCK), knowledge of content and students, knowledge of content and teaching and knowledge of content and curriculum. In this article, we will focus on only the domains of CCK, HCK and SCK. The first domain (CCK) refers to the mathematical knowledge commonly used or produced in a variety of settings, including outside teaching. This type of knowledge 'is not specialized understandings, but questions that typically would be answerable by others who know mathematics' (Ball et al., 2008, p. 399). Using an algorithm to find the answer for a subtraction problem is an example of CCK.

HCK is the knowledge of 'how the content being taught is situated in and connected to the broader disciplinary territory' (Jakobsen et al., 2012, p. 4642). This category involves the understanding of the subject's origins and principles, as well as how valuable it can be to students' learning. As a contribution, HCK enables teachers 'to make judgments about the importance of particular ideas or questions' of

students and address 'the discipline with integrity, all resources for balancing the fundamental task of connecting learners to a vast and highly developed field' (Jakobsen et al., 2012, p. 4642).

SCK is defined as 'the mathematical knowledge unique to the work of teaching' (Ball et al., 2008, p. 400). It 'involves an uncanny kind of unpacking of mathematics that is not needed—or even desirable—in settings other than teaching' (Ball et al., 2008, p. 400). It requires knowledge beyond solid content knowledge. The ability to present mathematical ideas during instruction and to respond to students' questions is an example of the tasks that teachers perform as part of their work, which requires mathematical knowledge unique to teaching mathematics. A list of mathematical tasks of teaching are listed in Figure 1.

In the Malawian context, the list of teaching tasks presented by Ball et al. (2008) reveals similarities with the tasks of Malawian mathematics teachers. Kazima et al. (2016) found that, although the Malawian context is very different from the US context, the work of teaching seems generally similar: 'some of the tasks are more commonly recognised by teachers as applicable to the Malawian context, while other tasks are found less relevant' (Kazima et al., 2016, p. 184). A task that seems to be unique to the Malawian context as opposed to the US context is the fact that Malawian teachers regularly make use of local resources as an integral part of teaching mathematics. Owing to the lack of didactical materials, teachers use natural resources, such as stones and sticks, for teaching specific mathematical topics in elementary education, and they make their own teaching and learning aids (Kazima et al., 2016). Although Ball et al. (2008) do not draw any inferences on the ways in which the teaching tasks are carried out in Malawi, they provide essential insights about the main characteristics that underpin the work of mathematics teachers, a starting point that supports further investigation of teachers' knowledge.

Methodology and Data Analysis

To explore how Malawian pre-service teachers understand the tasks of teaching mathematics in primary schools, we conducted a *qualitative case study* (Stake, 2006) with 23 pre-service teachers at the beginning of their teacher training. All of them volunteered to answer a questionnaire survey

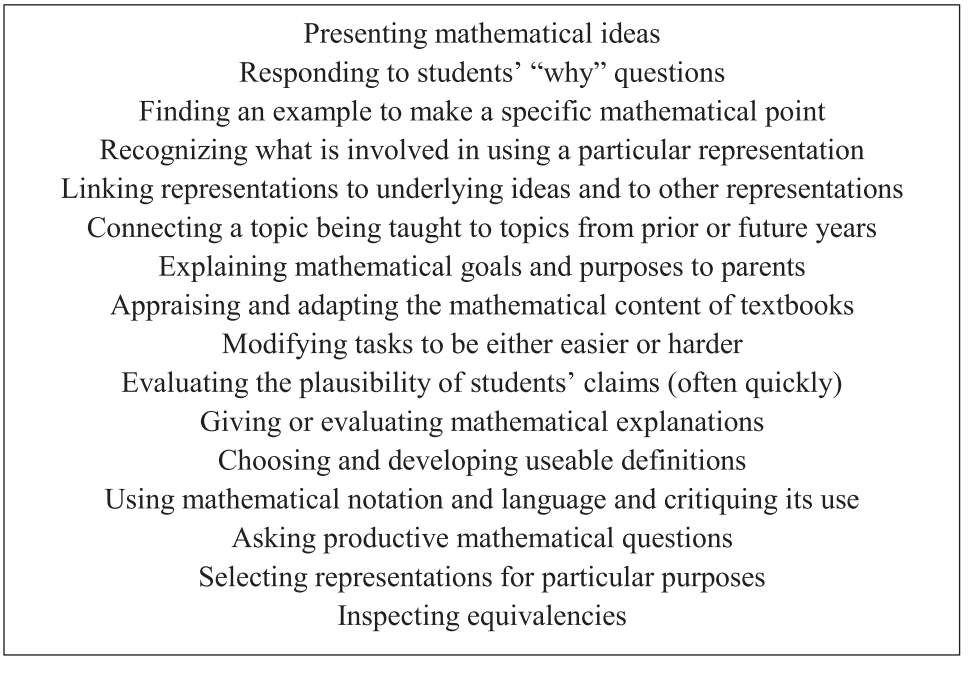

Figure 1. Mathematical tasks of teaching identified by Ball et al. (2008)

that consisted of open-ended questions about their teaching experience[1] (TE), preferences for mathematics in high school (MIHS) and interests in teaching mathematics during college (MIC). Based on the pre-service teachers' answers, six different profiles of pre-service teachers were identified. The six profiles, with the number of teachers in each of the profiles indicated, were: four pre-service teachers possessing TE, MIHS, and MIC; three having TE, but not MIHS and MIC; six with no TE, but with MIHS and MIC; four with no TE and MIHS, but with MIC; two with no TE, MIHS and MIC; and four with TE and MIC, but no MIHS. For the purpose of this paper, we considered one pre-service teacher from each of the six profiles. The list with the details of the teachers and their pseudonyms appears in Table 1.

Table 1. Selection of the research sample according to their profiles

Criteria of selection of the research sample	Pre-service teachers' anonymized names
TE/MIHS/MIC	Martin
TE/No MIHS/No MIC	Mario
No TE/MIHS/MIC	Patrick
TE/No MIHS/MIC	Clara
No TE/No MIHS/MIC	Daniel
TE/No MIHS/MIC	Denise

TE, Teaching experience; MIHS, preferences for mathematics in high school; MIC, interests in teaching mathematics during college.

Apart from the organisation and selection of the research sample, the questionnaire survey comprised a list of tasks of teaching framed by the theoretical constructs of Ball et al. (2008). The pre-service teachers ranked the level of significance of each task with the Malawian context in mind. One example from this list was the task: 'respond to children's why questions'. This specific segment of the questionnaire was a precursor for conducting individual interviews with the pre-service teachers.

In the interviews, the pre-service teachers identified and rated the significance of the tasks as important, very important or not at all important. They were also asked about their views, understanding and reasons for classifying the items on that scale. The pre-service teachers also provided insights into tasks that might be specific to the Malawian context, such as 'using natural resources in the classroom' and the type of knowledge pertaining to these tasks. This information was essential for better understanding the types of mathematical knowledge and tasks of teaching that pre-service teachers recognise as crucial for their in-field experience as a teacher as well as for their future profession.

The interviews were recorded, transcribed and analyzed using four categories, which included the significance of the mathematical knowledge used to handle the tasks of teaching in primary schools from the perspective of Malawian pre-service teachers. The four categories are: *CCK for teaching and learning*, *relating knowledge of out-of-curriculum content to HCK*, *the importance of SCK in interpreting students' errors and capacities* and *SCK: stimulating mathematics learning through different approaches*. These categories reflect the ways in which the pre-service teachers understood the tasks that might emerge in mathematics instruction, as well as the knowledge needed to tackle these tasks in the context of Malawian primary schools.

Findings and Discussion

CCK for Teaching and Learning

In this category, the pre-service teachers expressed their views and understanding about the importance of mathematical knowledge and how useful this can be for teachers and students in Malawi. The interview responses of three pre-service teachers are presented below to illustrate these views:

> Daniel: The teacher should have a very good knowledge of the content before going to the classroom, so **the learners can learn what they need to learn**.

Denise: It is important for the teacher to know the content because he or she can **help the learners to understand** when they are learning mathematics.

Clara: If the teacher knows the content, he will have **more confidence in the classroom**, and **the learners will know that he is wiser**.

In the interview extracts above, the three pre-service teachers acknowledge the importance of knowing the curriculum content for the benefit of students' learning. Mastering the curriculum content seems to be a crucial factor for effective teaching and learning of mathematical content. These views reinforce the idea that teachers should be capable of teaching in several ways when possessing in-depth knowledge of curricular mathematical concepts (Ball et al., 2008). However, one pre-service teacher provided a unique view of the teachers' method: 'teaching is about helping learners to learn from simple to complex, from known to unknown; and the curriculum [content] tells us the simple concepts that they need to learn' (Martin).

Daniel, Denise and Clara all acknowledge that good knowledge of the school's curriculum content is vital to ensure good quality teaching and student learning. However, it is unclear on what basis teachers decide what is important for students. In the particular case of Martin, the knowledge of subject matter is pictured as a method to encourage students to work from a topic they know (simple) towards an unknown topic (complex) or objective. From a practical perspective, the role of teachers in this context seems to be to place value on progressive learning of the subject matter.

Relating Knowledge of Out-of-curriculum Content to HCK

This second category explores the relevance of teacher knowledge needed to teach mathematics in primary schools, from the perspective of the pre-service teachers. Although scholars recognise the differences between HCK and knowledge of content and curriculum (e.g. Jakobsen et al., 2013), in this study, the pre-service teachers still refer to knowledge about content that is not in the curriculum as a curricular horizon rather than as a mathematical horizon. This view, however, varies among the pre-service teachers. In the following passages, two pre-service teachers demonstrated a tendency to prioritise content in the curriculum rather than content outside the curriculum.

Clara: The **ministry of education already applies what the learners have to know** at the primary level, so if the teacher is out of the curriculum, he can teach things that **are not intended for primary learners.**

Martin: **Since it is not part of the learners' curriculum**, I don't think it is important.

Clara and Martin's responses tend to lessen the importance of knowledge beyond the school curriculum. In Clara's view, for instance, it is not necessary for teachers to know out-of-curriculum content since it is the governmental authorities who determine what is necessary to be taught in classrooms. In the same vein, Martin does not see teachers playing a role in deciding what to teach, nor does he acknowledge the need for knowing why something is taught.

In contrast to the pre-service teachers' insights above, two other pre-service teachers demonstrate a more balanced point of view by illustrating positive and negative aspects of the teacher knowing and using contents not included in the school curriculum to teach mathematics.

Denise: It is not **so important** to know mathematics outside the curriculum, but the teacher needs to know it, in order **to make it easier for the learners**.

Daniel: So so … **The teacher might use it to answer some questions in the classroom, but it is not so important.** He needs to focus on the contents the school suggests to teach. Each standard [grade] in Malawi has its specific content to be taught so **the teacher can learn the content from the other standards to help the learner understand it**, but it is not so important for that particular level.

Denise and Daniel present a general view of the teachers' role that teachers need to possess knowledge outside the school curriculum in order to handle the tasks of teaching, such as answering

students' questions or making the content easier to learn. Daniel's understanding, in particular, seems to be explicitly linked to the knowledge needed to be used in tasks involving 'connecting a topic being taught to topics from prior or future years' (Ball et al., 2008, p. 400). This view implies that the knowledge at the mathematical horizon is relevant but only for providing links with content from higher school levels.

Patrick and Mario, in contrast, present a different view to Denise and Daniel. They suggested that teachers' knowledge should also include the ability to reflect on what they are teaching and to sequence the content of the curriculum, which is also needed for effective teaching (Ball et al., 2008).

> Patrick: It is very important because **they can reflect on what they are teaching**.
> Mario: Yes, it is important because, with other content, **you can explain better, you can mix it, and you can add new ideas**.

Patrick and Mario present a broad view of the relevance of the content outside of the curriculum, which implies that they think teachers should be open to exploring new ideas for the teaching of mathematics. Both pre-service teachers see teachers as taking an active role in mediating the school curriculum. They recognise the need for reflection on what is taught and how it can be improved. To acquire a better understanding of the content and new forms of teaching, for example, Mario believes that a teacher needs to experiment and try new ideas for teaching more effectively. This view reveals a link between the vertical and horizontal curriculum (Shulman, 1986), which are both important for mathematics instruction in primary schools. In the case of Patrick, incorporating 'complex concepts and new problems from real-life situations into the classroom may not be easy for the teacher, but it can challenge and stir creativity among the learners' (Patrick).

Patrick's assumption shows the type of knowledge that is particularly relevant and useful for teaching in Malawi: the knowledge at the mathematical horizon (Ball et al., 2008). In the literature, the concept of HCK refers to 'an awareness of how mathematical topics are related over the span of mathematics included in the curriculum' (Ball et al., 2008, p. 403). However, Patrick's idea of teaching complex concepts and incorporating problems from real-life situations into mathematics lessons seems to be a significant part of the teacher's knowledge and his/her ability to make links between curriculum topics. In this context, Kelly (1999) observes that, in some situations, curriculum content might 'limit the planning of teachers to a consideration of the content or the body of knowledge they wish to transmit or a list of the subjects to be taught or both' (p. 83). Knowledge of the content that lies outside the school curriculum can also be important to the work of teaching because it can help teachers to guide students to experience real-life situations that encompass multiple concepts (Freire, 1999).

The Importance of SCK in Interpreting Students' Errors and Capacities

Although expertise in the mathematical content both within and outside the primary school curriculum is an essential component of teaching, teachers are also faced daily with the task of evaluating the plausibility of students' claims. Any teacher who knows their students and their prior knowledge can identify, explain and predict what students can do or cannot do during learning activities (Freire, 1999). In this third category, we identified three sub-categories: thoughts of pre-service teachers concerning the limitations of identifying student capacities within their contextual settings; the role of the teacher in interpreting students' mistakes and identifying their capacities; and approaches that can be used for identifying students' problems. These insights are important to get a better picture of the pre-service teachers' understanding of the knowledge needed to explain why and how students make mistakes, and what knowledge and skills a teacher can use to minimise these mistakes. With regard to the first sub-category, three pre-service teachers spoke about the limits of knowing the students' capacities during mathematics lessons.

> Martin: Teachers should know what the learners can do, **but in Malawi, it is very difficult**! We have **so many children in the classroom** that you cannot know everyone. […] I used to teach in four classes, each with more than one hundred students.

Patrick: Learners can come across with a different challenge or problem in their life, so the teacher **needs to be familiar with it**, or the learners **will not be involved in the lesson**.

Denise: We need **to give them a chance to interact with what we are teaching**. Thus, they can help us **create different lessons** and **improve our curriculum**.

In Martin and Patrick's comments, students' abilities seem to play a significant role in defining how a teacher should teach in Malawi. However, they also believe that contextual factors, such as the large numbers of students in the classroom, limit teachers' abilities to meet the specific needs of students. Conversely, Denise sees the understanding of students' abilities as a resource that can help teachers to make effective decisions to improve their lessons. By interacting with students' thinking, teachers can change classroom practices, especially the approachability of the content being taught.

In contrast with Martin's, Patrick's and Denise's emphasis on students' abilities, three other pre-service teachers highlight the importance of interpreting students' mistakes and dealing with them in the classroom (second sub-category). While Martin, Patrick and Denise understand that teacher knowledge also includes the knowledge of interpreting students' mistakes and identifying their capacities, Daniel, Clara and Mario explained that it further includes the ability to guide students to discover the nature of their problems themselves.

Daniel: You are there to teach, so **you are there to check the mistakes**. You should correct them so they can have **the correct information**.

Clara: You can help them by **giving another view**, so they can understand mathematics and solve the problems.

Mario: The teacher must ask them, 'How did you come up with this answer? How did you solve it?' **This way, the teacher can know where the problem comes from.** Giving them the answer will not help them understand where they are wrong.

The views above encompass the third sub-category in which the pre-service teachers acknowledge the importance of helping students to become aware of their mistakes and of new ways of solving a problem. Daniel's, Clara's and Mario's comments describe this knowledge as an important skill for primary school teachers to possess in Malawi: teachers should not only know how to identify children's inaccuracies and errors but also help them to understand why these problems occur. Such an understanding reflects a tendency for recognising and valuing different ways of helping students. It confirms that knowing how to interact with students is an important characteristic of primary school teachers (Ball et al., 2008), as it gives students an opportunity to express their thoughts and ideas and reflect on what they need to learn. From a sociocultural perspective, this view is also a valid constituent: children's learning does not occur outside a particular context or in isolation from others but through someone more familiar with the topic (i.e., a teacher) and capable of understanding and support students' learning process (Vygotsky, 1987).

SCK: Stimulating Mathematics Learning Through Different Approaches

In this fourth category, the focus is on the way in which the Malawian pre-service teachers understand the different forms of teaching mathematics apart from what the textbook suggests. This component is a significant characteristic of SCK—a type of knowledge that allows teachers to engage children in mathematical activities in the classroom (Ball et al., 2008). The data from three pre-service teachers below shows multiple ways of teaching mathematics in primary schools in Malawi.

Mario: When learners have a different situation in their life, they are facing **a new challenge** that requires **new ways to solve it**. So, teachers can use these challenges to teach mathematics.

Patrick: In Malawi, we have Kwacha. So, **you can relate it in the classroom**. How much does it cost to go to Blantyre? You must negotiate and think, you know … Is it expensive? So, this can be a way to engage learners.

Denise: There are many different ways to teach mathematics. In Malawi, we use **place-value boxes** and **abacuses.** It is cheap and easy to manage in the classroom.

In the passage above, the three pre-service teachers illustrate different ways of thinking about multiple approaches for teaching mathematics: creating problem situations and using materials or instruments that can be manipulated for the students. With regard to such problem situations, Moura (2010) describes these as contextualised problems that allow teachers to use students' natural curiosity in order to solve problems from real-life situations. However, this type of approach should be intentionally organised to develop students' autonomy and critical thinking (Moura, 2010). In Patrick's comments, for example, we note that such an idea takes form in a common situation in Malawi: *transportation costs*. Patrick also argued that '[…] when coming to school, they [the children] have to take the minibus every day, so they can apply what they learn in class'. Therefore, contextual features appear to shape Patrick's view of SCK. Based on this finding, we can affirm that, in a Malawian setting, it seems to be important for teachers to know how to engage students in stimulating activities that challenge them, so that students can acquire concepts that emerge from and explain their reality.

Moreover, Denise presents an insightful perspective about the role of teaching tools. She understands that place-value boxes and abacuses are tools that teachers can use to help children develop a deep understanding of mathematics concepts. In this context, Miller and Stigler (1991) stress that tangible materials increase children's ability to perform mental calculations and representations, and that teaching mathematics through such materials improves the environment of the math classroom (Smith et al., 1999). Thus, the practical use of tangible materials in Malawi can also be a strong component in teachers' SCK, as it 'helps to spark students' imagination by letting them touch, move about, rearrange, and otherwise handle objects' (Kennedy, 1986, p. 9). The task of making teaching and learning more realistic and practical is also previously highlighted as a task that is more common in the Malawian context as opposed to other countries (Kazima et al., 2016).

Concluding Remarks

Scholars in educational science have outlined the importance of a distinctive brand of knowledge and skills unique to the work of teaching (Ball et al., 2008). In the framework developed by Ball et al. (2008), mathematical knowledge for teaching comprises two domains—subject matter knowledge and pedagogical content knowledge. Subject matter knowledge, in particular, has been extensively studied, as it has a significant impact on pre-service teachers' use of teaching strategies in classroom practice (Darling-Hammond & Bransford, 2005). In this paper, however, we reported on a study focusing specifically on the Malawian pre-service teachers' understanding of the knowledge related to the CCK, HCK and SCK—three domains of teachers' subject matter knowledge.

Our findings indicate that, although Malawian primary school pre-service teachers interpret the knowledge needed for teaching mathematics differently, they use solid arguments in parallel with the theoretical constructs proposed by Ball et al. (2008). By questioning the importance of the core elements that contribute to the effective teaching of mathematics (Ball et al., 2008), we observed that these pre-service teachers understand the knowledge of curricular mathematical concepts as crucial for shaping and supporting students' learning. In their view, in-depth understanding of curriculum content allows teachers to concentrate on what is essential for students to learn according to the curriculum. This ability is also seen as relevant for designing lessons that will increase student confidence as the content becomes more complex.

However, our findings also suggest that the participating pre-service teachers struggle with explaining basic characteristics of the knowledge at the mathematical horizon. Although pre-service teachers in Malawi recognise the relevance of mathematical knowledge outside the primary school curriculum, they discuss this within the sphere of the curricular, rather than the mathematical horizon. Furthermore, they regard the teacher's role in deciding what content students need to learn as limited, although they also think that teachers have ample opportunities to promote students' reflections on the nature of the mathematical concepts and their connections with different aspects of the school curriculum. These views imply a strong tendency to rely on the core curriculum as a primary source for teaching and learning at an equivalent standard, whereas the links with different school levels and real-life situations are understood as complementary sources for acquiring teaching knowledge. In sum, the participants in

this study concur that teachers should utilise a range of sources, methods and tools to promote students' understanding of mathematical concepts.

The insights that have emerged from this study contribute to the understanding of the ways in which pre-service teachers understand the knowledge needed to carry out tasks of teaching mathematics in primary schools in Malawi. However, further research is needed to ascertain whether pre-service teachers' understanding of what is useful for the work of teaching corresponds with the strategies they later adopt in their teaching practice. The present study is also beneficial for the enhancement of teacher training programmes, while contributing to a better understanding of the main concepts of the practice-based theory of mathematical knowledge for teaching.

Disclosure Statement

No potential conflict of interest was reported by the authors.

Note

1. For those pre-service teachers with prior teaching experience, the experience ranged from three months up to one school year, usually as volunteers or teacher assistants in primary schools.

ORCID

Everton Lacerda Jacinto http://orcid.org/0000-0002-5662-298X
Arne Jakobsen http://orcid.org/0000-0002-7427-5723

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