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Malawian preservice teachers' perceptions of knowledge at the mathematical horizon

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This paper examines how preservice primary teachers perceive mathematical horizon content knowledge for teaching in Malawi. Drawing on the practice-based theory of mathematical knowledge for teaching, the study highlights the importance of mathematical concepts and historical aspects needed for teaching, according to preservice primary teachers, at the beginning of their teaching education. Findings from the two cases revealed that despite differences in their perceptions, similarities also existed. This result provides a starting point for a better understanding of what composes mathematical horizon content knowledge and discusses implications for teacher-education training programs in Malawi.

Keywords: Malawian primary teacher education, mathematical horizon content knowledge, preservice teachers' perceptions.

Teacher's content knowledge for teaching

Becoming a professional at any workplace demands skills and knowledge to perform specific tasks, make decisions, and attend to what the profession requires. In this sense, becoming a teacher demands a specific type of knowledge that enables one to create sufficient conditions to trigger the students' learning (Davydov, 1999), develop their intellectual actions and mental functions (Vygotsky, 1987), and help them make sense of the world (Leontiev, 2007). In this context, why is this type of knowledge necessary to teach a subject properly? What difference does this knowledge have for the teaching of mathematics, and what are the implications for students learning in different contexts?

For decades, researchers around the world have investigated practices that can contribute to shaping teachers' knowledge. Shulman (1986), with his studies about teacher training in the USA, stands out in importance with his description of pedagogical content knowledge that extends beyond the specific topics of the curriculum. This type of knowledge represents a knowledge base that combines reflections on practical experiences and reflection on theoretical comprehension for teaching, a foundation that englobes the knowledge of the content, curriculum, students, contexts, and purposes/philosophies of teaching. Those elements, according to Shulman (1986), must be part of any educational program that forms primary and secondary teachers.

Of particular interest for mathematics teaching, Ball, Thames, and Phelps (2008) extended Shulman's (1986) ideas into two subcategories: *pedagogical content knowledge* (PCK) and *subject matter knowledge* (SMK). Whereas PCK includes the knowledge of content and students (KCS), knowledge of content and teaching (KCT), and the knowledge of content and curriculum (KCC), SMK comprises the common content knowledge (CCK), specialized content knowledge (SCK), and horizon content knowledge (HCK). Together, these six components offer a holistic perspective of what is useful and important for teaching. It also serves as a resource for addressing the

mathematical demands of specific teaching tasks in primary classrooms (Hill, Rowan, & Ball, 2005) and a potential tool that allows teachers to concentrate on what is essential for effective mathematics instruction (Ball et al., 2008).

Our focus is on teachers' mathematical knowledge beyond the school curriculum, HCK. Ball and Bass (2009) defined HCK as "a kind of mathematical 'peripheral vision' needed in teaching, a view of the larger mathematical landscape that teaching requires" (p. 1). It provides an awareness of "how the content being taught is situated in and connected to the broader disciplinary territory" (Jakobsen, Thames, Ribeiro, & Delaney, 2012, p. 4642) and "how mathematics topics are related over the span of mathematics included in the curriculum" (Ball et al., 2008, p. 403). Ball and Bass (2009) still explain that the knowledge at the mathematical horizon "is advanced knowledge that equips teachers with perspective for their work; it is not knowledge of the kind which they need to understand in order to explain it to students" (p. 27). Different from the other components in the teacher's MKT, the domain of HCK pays special attention to the processes involved in the creation and use of mathematical content rather than the content knowledge itself. It is a distinct knowledge that helps teachers engage and assist students to make sense of what is being taught from a global view of the subject matter.

In this article, we will focus on only one component of teachers' knowledge: HCK. Our aim is to provide a better understanding of how HCK is perceived in a different setting for teaching from which the theory was developed. To sustain this goal, we analyzed two cases taken from a larger research project that examines the preservice teachers in the context of Malawi. The main question addressed is: How do Malawian preservice primary teachers perceive the knowledge at the mathematical horizon at the beginning of their teacher education?

The study context

The study presented here is drawn from a larger research examining the preservice teachers' sense-making process of mathematical knowledge for teaching in Malawi. Twenty-three students from a two-years teacher-training program volunteered to participate. In this program, the mathematics education aims to develop preservice teachers' critical awareness of mathematical concepts, and its connections and ways of being used for solving problems in a social, environmental, cultural, and economic context (Malawi Institute of Education, 2017). The mathematical program's curricular structure and syllabus allow future teachers to interim practice and theory by integrating content and pedagogy during their mathematical lessons at the college. In the first two of six terms of the program, preservice teachers should take theoretical courses (arithmetic and algebra subjects, accounting and business studies, measurement and data handling, and teaching and learning theories), followed by monitoring visits in local schools. The two middle terms are dedicated to teaching practices. They go onto the field in pairs to gain practical and professional experience in teaching under the supervision of practicing teachers. In the last two terms, the preservice teachers go back to college. The program is now committed to the reflection on preservice teaching experiences, inclusion and further discussion about teaching methods, subject contents, educational policies, and frameworks.

In the larger study, we adopted two approaches to generate data from the participants. The first approach was set up through preservice teacher notions on what types of knowledge and skills they

thought could be most suitable for teaching mathematics in primary schools in Malawi. The main research instruments were a questionnaire including topics related to the participants' teaching experiences and subject preferences, and individual interviews addressing the constituents needed for carrying out the work of teaching in Malawi. The interview structure was designed to cover most of teaching scenarios from which the six domains of mathematical knowledge for teaching theory could emerge (Ball et al., 2008). The second approach – only applied in a subsequent phase of the study – focused on observations of the preservice teachers' lessons. By selecting "teaching episodes" from which particular aspects of MKT domains manifest, we create reflection moments with the preservice teachers aimed to explore how they perceive the utility of those domains in practice.

Once more, in this paper we explore one aspect of teachers' knowledge: HCK. The following data stem from a case study (Stake, 2006) with two Malawian preservice primary teachers presenting distinctive ways to perceive HCK. The data collected was transcribed and condensed into a summary format. This format helped us establish analysis categories, with the MKT framework as a base. Those categories were expected to emerge from the preservice teachers' responses during the interviews, and the first pieces of evidence were projected to provide information on how the participants perceive HCK in the Malawian school settings. The idea was also to explore the basis and influences that shape the preservice teachers' perceptions before they went to the field work.

Preliminary Findings

Intendence of placing contextual knowledge in teachers' HCK

In this category, we analyzed the case of Patrick, a 20-year-old student possessing no teaching experience prior to entering the teacher training college. His parents are workers from the rural area and live in a village nearby the college. His favorite subjects in high school included biology, physics, and mathematics, while his interests lie in teaching mathematics and foundations studies.

During the interview, Patrick recognized the need to distinguish the knowledge and skills needed for teaching mathematics in primary school in Africa. This position, followed by the passage below, were pieces of evidence for understanding what Patrick might perceive as an HCK. The passage occurred during a discussion about the knowledge needed for teaching mathematics beyond the primary school curriculum.

Researcher: Ok Patrick, now... let's talk about the knowledge that a teacher needs to know beyond the curricular content.

Patrick: Sorry, I don't understand the question. Can you repeat, please?

Researcher: Yes... we talked about the importance for teachers to know the content, the curricular content in primary school, right? They also need to know the students, ok? But, is there anything else teachers need to know apart from those we have discussed? For example, numbers. If I decide to become a teacher in Malawi, what do I need to know to teach numbers? If I know the content, the students, and a couple of teaching techniques, is that enough?

- Patrick: Hum... No! I think you should know more about Malawi... the Malawian context!
- Research: Ah... Ok! You can say that! So, let's put it this way... In terms of mathematics teaching, you said a teacher needs to have good knowledge of the curricular mathematics. But how about the mathematics outside of curriculum? [primary school curriculum]
- Patrick: Yes, it is also important! Because there are other concepts that can explain some situations better. And also, you can apply those concepts to a situation. What is in the curriculum is good for planning, you know... but sometimes, the concepts in the curriculum are not enough. So, you can put them... you can mix them with those that are in the curriculum to explain something. So I think it's very important to do so.
- Researcher: Can you give an example of that?
- Patrick: In mathematics, for example... in Malawi we do farming. So, when you are teaching maybe some examples could be about farming, they [primary school teachers] should go further about agriculture, so the learners can reflect on what they do in their families as they do farming.
- Researcher: So, is it important to give examples like this in class?
- Patrick: Yes, when you are teaching, you have to give many examples. Those examples should be linked to real-life situations because it will be easy for them [students] to reflect on what they know, so they can understand and apply it [mathematics] in real life.

The forward reference shows that Patrick acknowledges not only the importance of curricular concepts in teaching but also the limits of teaching mathematics using only those concepts. He identifies that although the curriculum is essential for the teachers' planning activities, it might restrict the work of teaching from a general perspective. Patrick's perception of knowledge outside the school curriculum does not seem to corroborate with the suggested definition by Jakobsen et al. (2012), but it arises as part of a broader framework where mathematical knowledge takes place. Zazkis and Mamole (2011) explain that teachers' knowledge at the mathematical horizon also includes aspects in both the inner and outer horizons of an object. It encompasses the "connections between different disciplinary strands and contexts in which the object may exist" (p. 9). Students will only benefit from some of those features.

HCK as a contextual feature in teacher's knowledge is also a subject of interest for Zhang, Zhange, and Wang (2017). They pointed out that although HCK is directly connected to knowledge of a pure mathematical content, contextual factors can be adapted to the definition provided by Ball and Bass (2009), a type of knowledge that embraces

aspects of the mathematics that, while perhaps not contained in the curriculum, are nonetheless useful to pupils' present learning, that illuminate and confer a comprehensible sense of the larger significance of what may be only partially revealed in the mathematics of the moment (p. 6).

Therefore, in Patrick's case, we can see that this dimension manifests in the form of cultural values and explicit knowledge of the ways and tools needed in the discipline (Jakobsen et al., 2000), but it does not relate directly to the aspects of mathematical content contained in the curriculum. The example of the agricultural field provided by Patrick might not be transferred to mathematics, but it represents the great world in which mathematics exists. *If a teacher wants to create in students the need for understanding and applying the concepts, he or she needs to think beyond the school curriculum*, explains Patrick.

Shoemaker (1989) explains that the acknowledgment of the relevance of contents hosted outside the traditional curriculum helps prospective teachers increase the opportunities for students to make meaningful associations with other areas of study, and develop new forms of abstractions of the real world. As a result, school subjects become more attractive, and students can appropriate concepts that are inherent to the world (D'Andrade, 1981). By doing so, teachers can facilitate students' learning by using concrete ideas and expanding them into abstract forms and new, concrete applications (Davydov, 1999).

HCK as an awareness of students' future needs and history of mathematics

Our focus now is on Mario's case, a preservice teacher six years older than Patrick. Mario used to live with his family in a district in the central region of Malawi. His mother and father are retired, but both had worked as primary school teachers. After completing high school, he worked as an assistant teacher in a public primary school for three years. His favorite subjects were agriculture and social studies. At the teacher-training program, he still demonstrated a preference for teaching in those areas, including English and the local Malawian language, Chichewa.

In the interview, Mario presented two distinct ways to perceive the knowledge beyond the school content needed for teaching. He made emphasis not only to the importance of knowing the primary curricular contents but also to the knowledge needed to improve the quality of primary education by liking those to superior educational levels. The passage below occurred at our first interview with Mario, and it illustrates how he perceives the importance of having knowledge outside of the primary curriculum in Malawi.

Researcher: Mario... what does a teacher need to know to teach in a primary school in Malawi? Does he need to know the content, right?

Mario: Yes, because knowing the content you will be able to teach, and without the content, you don't know what to tell the learners.

Research: But he needs to know just the contents of the curriculum?

Mario: The content in the curriculum is important, but also you can extend it to the curriculum of secondary level. You can go higher! So you know what the upper classes is particularly doing about a particular topic is good because you can make a link to that. For example... in mathematics, we have geometry in upper level... we teach them how to find the angles or areas of triangles, so you if you don't have that knowledge you can not teach triangles in lower classes. So a primary teacher needs that knowledge!

By analyzing Mario's comments on what is needed for a teacher to know rather than what the curriculum suggests, we can see that he values the idea of establishing connections between the primary school curricular concepts and concepts from higher classes. In Mario's view, the benefits of knowing mathematics from higher classes appear to be relevant because it facilitates the teacher's work in covering ideas that can be related to the current school mathematics content.

The suggestion that teachers' knowledge demands more than just knowing curricular contents is pertinent to understanding what Mario believe to be necessary for teaching mathematics in primary schools in Malawi. However, the idea of knowing how curricular mathematical topics are related to a more general curricular concept represents only a small portion of what constitutes HCK. Jakobsen et al. (2012) attempted to clarify that HCK implies not only the knowledge about curricular development of the contents but it also involves the knowledge about "how the content being taught is situated in and connected to the broader disciplinary territory" (p. 4642). It should go beyond the merely curricular progression where scholar concepts take place; in the case of the advanced mathematics, HCK emerges in understanding elementary mathematics from an advanced viewpoint, and vice versa (Klein, 2016).

The next passage is a sequence of the transcription above from which Mario expressed a second idea about the type of knowledge needed for a teacher to know rather than just curricular demands. The dialogue occurred when we asked him about what type of knowledge and skills are needed for planning a lesson activity in mathematics.

Researcher: When a teacher plans a lesson in Mathematics what things does he or she needs to know? I mean... beyond what the curriculum suggests?

Mario: As a teacher, you have to know why is there mathematics and who discovered the mathematics. Because when you are teaching learners, they have so many questions that if you don't know how to answer those questions you cannot help them. Some learners need to know why we need mathematics, who discovered this theory and these concepts? Who came up with this formula? And why? So he or she should be able to answer those questions. And for you to answer those questions, you should know the history behind the mathematics.

Researcher: So do you agree that it is important for primary school teachers to know the history of mathematics, I mean... the processes that led people to create the concepts?

Mario: Yes, I agree with that!

Researcher: But is it not too much for teachers? Generally, teachers give a task and some exercises.

Mario: No, it is not too much! This is part of the work. Because I want to take the learners from the very deep so they can easily understand what is about... so I want to take them from the very deep of what is really mathematics and all about mathematics. So they will be able to understand whatever the teacher is saying.

In the first part of the passage above, Mario argued in favor of the ability to think about the mathematical concepts critically. He suggested that knowing only the present form of concepts might not be enough for learners to have a complete conceptual understanding of what is being taught, so a teacher needs to be aware of the meaning and general principles that grip the existence of mathematics. Thus, the knowledge about the historical development that formed the concepts reinforces teachers' conceptual understanding by giving insights into how the concepts were formulated and transmitted culturally (Shulman, 1982). Such awareness, consequently, permits them to establish associations and generalizations among other areas (D' Andrade, 1981).

Knowledge about the historical development of concepts is also important for one to perceive mathematics as a human production (Moretti, 2007). Studies by historical-cultural theorists have shown that the historical development of concepts occurred from concrete situations from which humans felt the need to solve them. Caraças (1984) explains that a number system, for instance, should not be seen as a pure product of human thinking because humans did not acquire the idea of numbers and then began to count. Natural numbers were formed slowly due to the daily practice of counting, rational numbers from measurements, real numbers from the logical compatibility of different acquisitions (Caraças, 1984). Being aware of the logical-historical aspects of mathematics, teachers have an opportunity to create conditions for students to establish systematic ways to understand the dialectical principles of concepts (Davydov, 1982). This type of knowledge, according to Jankvist, Mosvold, Fauskanger, and Jakobsen (2015), is one of the main characteristics that comprises the mathematical horizon knowledge of teachers.

Conclusion

In the course of a larger research that investigates the preservice teachers' sense-making process of mathematical knowledge for teaching, the present article provided analyses on the perceptions of two participants regarding HCK. The findings revealed that both preservice teachers possess distinct ways of perceiving the knowledge outside of the curriculum and that those perceptions can contribute to a better understanding of what primary preservice teachers believe to be needed for knowing further than what the mathematical curriculum suggests.

These findings also have important implications for further research and teacher education practices. Knowledge about topics that might arise in learners' future studies is important for a teacher to possess, but it does not necessarily cover the idea of the advanced mathematical horizon proposed by the literature. HCK, in the sense of advanced mathematics horizon, encounters the understanding of concepts teachers want to teach in its totality considering its historical and cultural processes of production, representation, and validation (Shulman, 1986). In the context of teacher education, these results vindicate for teacher training programs provide even more insights, supports, and opportunities for reflections on the types of knowledge that anchor the broader disciplinary territory where mathematics takes place.

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