The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa

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Thesis accepted for the degree *Doctor of Philosophy* in *Mathematics Education* at the Potchefstroom Campus North-West University

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis entitled: **The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa** is my own original work and that I have not previously submitted it to any other university for a degree.

Signature

11 August 2022

Date

DEDICATION

I dedicate this thesis to:

My son, Tshimologo, your existence has brought meaning unto my life. You indeed ushered the new beginnings in the journey of my becoming. Do not let your dreams become orphans while you are still counted amongst the living.

My mother, Mrs. Maria Mabotja, your words "*Hlokomela dithuto tsa gago ngwanaka*" are the cornerstone of my academic journey. Ke a leboga Mme Motswadi! This is for you mom!

My mentor, Dr MK Maphoto, thank you for your great impact on my life. This is yet another product of your impact in the journey of my becoming.

ACKNOWLEDGEMENT

First and foremost, I give all thanks and praise to Great and awesome God whose love, peace and grace sustained and energised me. E sale o le Modimo, o sa balwe le dilemo.

- Prof M.S. van der Walt, my promoter, thank you for your scholarly wisdom and supervision as well as your encouragement throughout this study.
- Prof J.J.J. de Beer, my co-promoter, thank you for your contribution and scholarly insight throughout this journey. Thank you for your consistent courage and motivation. Chatting about CHAT remains more than a conversation!
- Mr K.F. Mabotja and Mrs M.M. Mabotja, my parents, thank you for nourishing me into who I am today. Words will never be sufficient to articulate how grateful I am for your loving kindness.
- Dr M.K. Maphoto, I am thankful for your great impact on my life and journey. Your support and prayers have never gone unnoticed.
- Prof J.S. Brits, thank you for your support, critical eye and courage throughout this journey. At times, I felt like giving up, but Prof you stood by me!
- Dr M.C. Du Plooy, thank you for your critical eye and guidance throughout this journey.
- My brothers (Hans, Thapedi and Chuene), sisters (Eliza and Philia), this work has taken much of our family time. Bakone ba ntsi dikgolo, ke leboga thekgo le lerato la lena ka dinako tsohle.
- Motlatso Mabobe, thank you for your patience and support throughout this journey.
- A special thanks to teacher educators, ethnomathematics expert, and student teachers who volunteered to participate in this study.
- To all my many friends, in particular Richard Moloto and Samson Nkosi, thank you eagles for always reminding me to focus on the vision. Let us keep on soaring!
- Advocate Lesiba Benedict Moshoeu, Mr Puleng Rankweteke, and Ms Promise Mafokwane, talking about our studies strengthened me in this journey.
- A heartfelt thanks to FUCHS foundation for sponsoring the workshop.
- North-West University and Sol Plaatje University for financial support.
- Gill Hannant, thank you for proofreading and editing this thesis.

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TO WHOM IT MAY CONCERN

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ABSTRACT

The rationale for this study was to investigate the affordances of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa. Over the past decades, researchers have shown that mathematics teachers lack awareness of ethnomathematics approaches and how they can be integrated into the classroom. Among the possible reasons for the teachers' insufficient pedagogical knowledge in ethnomathematics is that pre-service mathematics teacher education is not adequately preparing student teachers in ethnomathematics. Consequently, the study sought to answer the research question: What are the affordances of ethnomathematical perspectives in pre-service mathematics teacher education? Through this question, the study explored, among others, teacher educators', an expert's and student teachers' understanding and perceptions of ethnomathematics, and how mathematics education modules prepare student teachers for ethnomathematics. Furthermore, the ethnomathematics intervention was conducted to scaffold, and enhance student teachers' professional development through practical ways in which they can integrate ethnomathematics in their prospective classrooms.

The study adopted a multiple case study, which involved a total of 24 participants (6 teacher educators, an ethnomathematics expert, and 17 student teachers) in pre-service mathematics teacher education from three selected universities in South Africa. Semi-structured interviews were employed to collect data from teacher educators, the ethnomathematics expert and student teachers. In addition, a pre-intervention questionnaire and focus group interviews were adopted to collect data from student teachers' participants. Document analysis also served as a data collection method. Ethnomathematics intervention was used to scaffold student teachers' professional development on ethnomathematics pedagogies. As a result of COVID-19 and time constraints, the intervention was conducted in one of the three selected universities. Engeström's (1987) third-generation Cultural-Historical Activity Theory (CHAT) was adopted in the second stage of data analysis to provide insight on challenges that either promote or prevent the integration of ethnomathematics.

The findings of this study revealed, amongst others, that ethnomathematics may enhance learners' understanding of abstract mathematics concepts; there is a lack of focus on ethnomathematics in pre-service mathematics education; and the need to prepare student teachers in ethnomathematics to change their mindset about the nature of mathematics. Further findings revealed that a lack of contextualised mathematics textbooks, technology approaches, and time constraints are some of the factors that could hinder effective integration of ethnomathematical perspectives in mathematics classrooms. With regard to technology approaches, it was found that the 21st century classrooms are characterised by learners who are technologically driven and, as such, using ethnomathematics may possibly be irrelevant to them. Recommendations for curriculum material development, pre-service and in-service mathematics teacher education; and future research in terms of intervention workshops and student teachers' actual classroom practices were suggested.

Keywords

Affordances, ethnomathematics, culturally relevant pedagogy, pedagogy of play, indigenous knowledge systems, mathematics, pre-service teacher education, self-directed learning, embodied, distributed and situated cognition, pedagogical content knowledge

OPSOMMING

Die doel van die studie was om die affordansies van etnowiskundige perspektiewe in voordiens Wiskunde-onderwysersopleiding aan geselekteerde universiteite in Suid-Afrika te verken. Oor die afgelope dekades het navorsers getoon dat wiskunde-onderwysers nie bewus is van etnowiskundebenaderings en hoe hulle in die klaskamer geïntegreer kan word nie. Een van die faktore wat aan hierdie gebrek aan bewustheid toegeskryf word, is 'n gebrek aan fokus op etnowiskunde in voordiens-wiskunde-onderwysersopleiding. Gevolglik, het die studie gepoog om die navorsingsvraag te beantwoord: Wat is die affordansies van etnowiskundige perspektiewe in voordiens Wiskunde-onderwysersopleiding? Deur hierdie vraag het die studie onder meer onderwyseropvoeders, kundige en student-onderwysers se begrip en persepsies van etnowiskunde ondersoek, en hoe wiskunde-onderwysmodules studente-onderwysers vir etnowiskunde voorberei. Verder, is die etnowiskunde-intervensie uitgevoer om onderwysstudente se professionele ontwikkeling te steier en te verbeter deur praktiese maniere waarop hulle etnowiskunde in hul voornemende klaskamers kan integreer.

Die studie het veelvuldige gevallestudies aangeneem wat 'n totaal van 24 deelnemers (6 onderwyseropvoeders, ‘n etnowiskunde-kundige en 17 studente-onderwysers) in voordiens-wiskunde-onderwyseropleiding van drie geselekteerde universiteite in Suid-Afrika betrek het. Data is ingesamel deur middel van semi-gestruktureerde onderhoude met onderwyseropvoeders, en die etnowiskunde-kundige, voor-intervensievraelys en fokusgroeponderhoude met student-onderwysers, en dokumentontleding. Etnowiskunde-intervensie is gebruik om onderwysstudente se professionele ontwikkeling oor etnowiskunde-pedagogieë te steier. As gevolg van COVID-19 en tydsbeperkings is die intervensie by een van die drie geselekteerde universiteite uitgevoer. Engeström (1987) se derdegenerasie Kultuurhistoriese Aktiwiteitsteorie (KHAT) is in die tweede stadium van data-analise as 'n navorsingslens aangeneem om insig te gee oor faktore wat die integrasie van etnowiskunde óf bevorder óf belemmer.

Die bevindinge van hierdie studie het onder andere aan die lig gebring dat etnowiskunde leerders se begrip van abstrakte wiskundekonsepte kan verbeter; daar is 'n gebrek aan fokus op etnowiskunde in voordiens-wiskunde-onderwys; en die behoefte om studente-onderwysers in etnowiskunde voor te berei om hul ingesteldheid oor die aard van wiskunde te verander. Verdere bevindinge het aan die lig gebring dat 'n gebrek aan gekontekstualiseerde wiskundehandboeke, tegnologiebenaderings en tydsbeperkings van die faktore is wat effektiewe integrasie van etnowiskundige perspektiewe in wiskundeklaskamers kan belemmer. Met betrekking tot tegnologiebenaderings is gevind dat die 21ste eeuse klaskamers gekenmerk word deur leerders wat tegnologies gedrewe is en as sodanig kan die gebruik van etnowiskunde moontlik vir hulle irrelevant wees. Aanbevelings vir kurrikulummateriaalontwikkeling, voordiens- en indienswiskunde-onderwysersopleiding; en toekomstige navorsing in terme van intervensiewerkswinkels en student-onderwysers se werklike klaskamerpraktyke is voorgestel.

Sleutelwoorde:

Affordansies, etnowiskunde, kultureel relevante pedagogie, spelpedagogie, inheemse kennisstelsels, wiskunde, voordiensonderwysersopleiding, selfgerigte leer, beliggaamde, verspreide en gesitueerde kognisie, pedagogiese inhoudskennis

ABBREVIATIONS

ANA	Annual National Assessments
BEd	Bachelor of Education
CAPS	Curriculum and Assessment Policy Statement
CAR	Classroom Action Research
CCK	Common Content Knowledge
CDE	Centre for Development and Enterprise
CHAT	Cultural Historical Activity Theory
CHE	Council of Higher Education
CL	Collaborative Learning
CRP	Culturally Responsive Pedagogy
DA	Document Analysis
DBE	Department of Basic Education
DBR	Design-Based Research
DHET	Department of Higher Education and Training
E	Expert
ECD	Early Childhood Development
ES	Electronic Submission
ESDC	Embodied, Situated and Distributed Cognition
F2F	Face-to-Face interview
FET	Further Education and Training
FG	Focus Group
GET	General Education and Training
HCK	Horizon Content Knowledge
IBL	Inquiry-Based Learning
IKS	Indigenous Knowledge Systems
IMKS	Indigenous Mathematical Knowledge Systems
IP	Intermediate Phase
IT	Information Technology
ITE	Initial Teacher Education
KCC	Knowledge of Content and Curriculum
KCS	Knowledge of Content and Students
KCT	Knowledge of Content and Teaching
LOLT	Language of Learning and Teaching
MCK	Mathematics Content Knowledge

MKT	Mathematics Knowledge for Teaching
MRTEQ	Minimum Requirements for Teacher Education Qualifications
NCTM	National Council of Teachers of Mathematics
NSC	National Senior Certificate
PBL	Project-Based Learning
PCK	Pedagogical Content Knowledge
PoP	Pedagogy of Play
PQ	Pre-intervention Questionnaire
SADBE	South Africa Department of Basic Education
SCK	Specialised Content Knowledge
SDL	Self-Directed Learning
SMK	Subject Matter Knowledge
SP	Senior Phase
ST	Student Teacher
TE	Teacher Educator
TI	Telephonic Interview
TIMSS	Trends in International Mathematics and Science Study
WIL	Work-integrated learning
ZPD	Zone of Proximal Development
ZPTD	Zone of Proximal Teacher Development

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CHAPTER 1

BACKGROUND AND CONTEXT OF THE STUDY

"Africa is in serious trouble, not because its people have no foundations to stand on, but because ever since the colonial period, they have had their foundations removed from under them" (Joseph Ki-Zerbo,1990, cited in Gerdes, 2014, p. 21).

1.1 INTRODUCTION

The above-mentioned extract from the late Professor Joseph Ki-Zerbo (1990, cited in Gerdes, 2014, p. 21), who was a well-renowned African thinker, scholar, and historian from Burkina Faso, resonates with this research study as it advocates for restoration of cultural pedagogies and epistemologies as essential foundations towards understanding mathematics in South African classrooms. South Africa (known as the rainbow nation), like many other African countries, reflects cultural diversity. It is rich with diverse cultural backgrounds and practices of different cultural groups. Such diversity is evident in various cultural practices and activities that can be traced from ancient people to the present generations. South Africa, as a country with diverse cultural backgrounds, offers great possibilities for exploring ethnomathematics studies. In such diverse cultural backgrounds, lie a story of mathematical concepts and skills. To mention a few examples, the traditional houses various cultural groups build and live in; the indigenous games (e.g, morabaraba, diketo, kgati) that are dominantly played in South Africa; and the beadwork and weaving which exist in many South African cultures contain a lot of mathematical concepts (Chahine, 2016; Machaba & Dhlamini, 2021; Madusise, 2022; Moloi, 2020; Seroto, 2012; Van der Walt et al., 2019). The contention is that mathematical concepts may be learned and taught by using learners' cultural practices and activities in the learning processes. It is in these cultural practices or activities that learners' mathematical foundations may be established.

The curriculum and assessment policy statement (CAPS hereafter) recommends the inclusion of learners' social, cultural, and environmental backgrounds in contextualising mathematics as reflected in one of the specific aims (South African Department of Basic Education [SADBE hereafter], 2011). The aim provide evidence that the CAPS mathematics curriculum acknowledges that learners come to their learning environments with a wealth of experiences shaped by their cultural practices and activities which should be utilised to their benefit in mathematics. Furthermore, one of the principles of CAPS is premised on “Valuing Indigenous Knowledge Systems (IKS): Acknowledging the rich history and heritage of this country as important contributors to nurturing the values contained in the constitution” (SADBE, 2011, p. 5). The principle proposes the importance of appreciating IKS as valuable contexts through which learners may appreciate their heritage. CAPS appears to embrace opportunities to incorporate IKS into school mathematics.

Regrettably, research has generally shown that mathematics is often taught isolated from learners’ cultural backgrounds and foundations (D’Ambrosio & Rosa, 2017; Mosimege, 2015; Moloi, 2020; Van der Walt et al., 2019). The contention is that mathematics is taught from an abstract point of view which does not take into consideration concrete contexts from learners’ cultural backgrounds. As a result, in recent years there have been numerous mathematics teachers and researchers advocating the inclusion of ethnomathematics as a new pedagogical paradigm in mathematics classrooms (D’Ambrosio & Rosa, 2017; Moloi et al., 2021; Muhammad et al., 2020; Van der Walt et al., 2019). Ubiratan D’Ambrosio, a mathematics educator and professor from Brazil, first introduced the concept of ethnomathematics as a mathematics found in identifiable cultural practices (D’Ambrosio, 1985). Thus, it is based on the notion that cultural groups have developed strategies of mathematising, that is, they have developed though culture or cultural practices their own strategies for observing, comparing, classifying, ordering, measuring, quantifying, and inferring (D’Ambrosio, 2016). The assertion is that ethnomathematics acknowledge that the manner in which various cultural groups solve problems in their everyday life resembles mathematical ideas.

Numerous studies have shown that ethnomathematics improves learners’ performance in mathematics (Achor et al., 2009; Unodiaku, 2013), cognitive abilities and competences (D’Ambrosio, 1985, D’Ambrosio & Rosa, 2017; Herawaty et al., 2019, Moloi, 2013, 2014, 2015; Rosa & Shirley, 2016; Sharma & Orey, 2017; Widada et al., 2018) in mathematics. In this regard, it can be argued that cultural contexts can strengthen learners’ awareness that mathematics forms an integral component of their everyday life and also improves their views about the nature of mathematics (Fouze & Amit, 2018; Moloi et al., 2021; Mosimege, 2020; Nabie, 2015; Owusu-Mensah & Baffour, 2015; Rosa & Orey, 2016; Van der Walt et al., 2019). The assertion is that ethnomathematics provides learners with opportunities to relate mathematics embedded in cultural practices to school mathematics. Thus, it is important to identify ways to link their cultural background to mathematics as this may strengthen their abilities to establish mathematical connections. When learners experience mathematics in their cultural contexts, it suddenly becomes meaningful—their attitude changes and they become interested in mathematics (Van der Walt et al., 2019). Hence, Widada et. al (2018) argued that in order to enhance learners' mathematical representations, it is important to include culturally based contexts linked to horizontal mathematics from ethnomathematical perspectives.

The implications of ethnomathematics in the teaching and learning of mathematics legitimise a focus in pre-service mathematics teacher education. Katsap and Silverman (2008) argued that there is no reason for teacher education to avoid the inclusion of ethnomathematical perspectives in their curricula. From Orey and Rosa's (2007) point of view, teachers' under-preparedness limits the possibility for integrating the ethnomathematical perspectives into the mathematics classrooms. These assertions provide evidence that teachers cannot use pedagogies that are beyond their knowledge. When student teachers are trained in ethnomathematics, they may develop knowledge and skills to infuse it in their prospective classrooms. Hence, Gavarrete (2012, cited in Rosa & Gavarrete, 2016) foregrounded that appreciation of mathematics concepts situated within cultural practices will empower student teachers with pedagogical knowledge that positions them to contextualise school mathematics using everyday contexts. In this regard, it can be contended that a lack of focus on ethnomathematics will likely leave student teachers underprepared to integrate ethnomathematics into their prospective classrooms. These assertions are important for the current study as they strengthen the basis to investigate the preparation of student teachers for ethnomathematical perspectives in their mathematics education training.

Furthermore, the contention to focus on pre-service mathematics teacher education is found in an African proverb '*Mmala wa kgomo o bonala namaneng*' which, loosely translated, is '*A colour of the cow is reflected in a calf*.' This proverb suggests that student teachers are a mirror reflection of the pre-service teacher education system which prepares them. The student teachers' identities and philosophical orientations are developed during their training. The theoretical and practical knowledge they develop in pre-service mathematics teacher education has a direct implication on their prospective mathematics classrooms. Simply put, pre-service mathematics teacher education is the focal point towards developing student teachers' professional development as prospective teachers. Therefore, this study shares the same view as Balfour (2019), that the positioning of Indigenous Knowledge Systems (in this case ethnomathematics) in the curriculum (in this case pre-service mathematics teacher education) is essential towards reimagining pedagogy and teaching methodologies.

Furthermore, the current state of mathematics in South Africa, characterised by learners' underachievement as evident in both international and national assessments, legitimises a focus on pre-service teacher education as a system that produces the teachers. Moreover, the Centre for Development and Enterprise's (CDE) report (2014) lamented teachers' inadequate pedagogical knowledge and subject content knowledge for learners' under-achievement. These key factors imply that pre-service teacher education is not adequately equipping student teachers with sufficient pedagogical knowledge and skills necessary to teach mathematics. Taylor and Taylor (2013) maintained that pre-service teacher education should be at the forefront of developing student teachers with mathematical understanding as well as innovative pedagogical epistemologies. To reiterate, this study pointed ethnomathematics as one of the innovative pedagogies relevant to the mathematics classroom. Thus, student teachers should not only develop subject content knowledge but also be able to use different pedagogical strategies to present mathematics meaningfully in their classrooms (Adler & Venkatakrishnan, 2014).

1.2 THE GAP FILLED BY THIS STUDY

Ethnomathematics plays an essential role in the contextualisation of mathematics. Numerous studies have explored how ethnomathematics can be used as a pedagogical approach to contextualise mathematics concepts in the classrooms. For example, indigenous games (Fouze & Amit, 2018; Moloi, 2013; Moloi et al., 2021; Mosimege, 2020; Nabie, 2015; Nkopodi & Mosimege, 2009; Owusu-Mensah & Baffour, 2015; Van der Walt et al., 2019; Dewah & Van Wyk, 2014), indigenous buildings (Ditasona, 2018; Muhammad et al., 2020; Seroto, 2006, 2012; Suharta et al., 2017), and music (Buranich, 2016; Evangelopoulou, 2014; Helsa & Hartono, 2011; Kalpana, 2015; Mbusi, 2011; Tokhmechian & Gharehbaglou, 2018; Van der Walt et al., 2019) are considered valuable sociocultural contexts that can play an essential role in contextualising mathematics.

Despite the benefits of ethnomathematical perspectives in mathematics education learning environments, there has been limited research on ethnomathematical perspectives in pre-service mathematics teacher education within the South African context (Chahine et al., 2013). Although previous research conducted by Spangenberg (2020) focused on mathematics teacher education in South Africa, the emphasis was on teachers who have completed an initial teacher education degree. Thus, research done has been mostly limited to teaching and learning in primary, secondary, and in-service mathematics teacher education; little or no emphasis has been devoted to pre-service mathematics teacher education in South Africa. Katsap and Silverman (2008) pointed out that there is no reason to avoid the integration of ethnomathematical perspectives in the mathematics curriculum of teacher education programmes. Hence, Gerdes (2014) considered teacher education as "a strategic place for debate and experimentation with cultural embedding of mathematics education" (p. 147). However, the existing research is inadequate for pre-service mathematics teacher education where student teachers' pedagogical identities, beliefs, and philosophies about teaching and learning of mathematics from ethnomathematics perspectives are established, if not enhanced. The paucity of research in this context therefore leaves student teachers under-prepared in terms of ethnomathematics epistemologies and approaches which they could use in their prospective mathematics classrooms. Hence, Spangenberg (2020) argued that "many student teachers in South Africa find it challenging to relate mathematics concepts with learners' cultural practices" (p. 103). As a result, there is "a need for research invested in Mathematics [student] teachers' PCK [pedagogical content knowledge] in their own local and IK contexts, and their own readiness to contextualise and mathematise it" (Van der Walt et al., 2019, p. 220). It is therefore against this background that this research study sought to explore the affordances of ethnomathematics in pre-service mathematics teacher education in South Africa. The term 'affordances' was coined by Gibson (1979) to explain an action possibility formed by the relationship between an agent and its environment. In addition, Norman (1988) perceived that affordances reflect the possible relationships among actors, objects, and the physical manipulation of the objects. In this study, 'affordances' refers to the possibilities of an action or object (De Beer & Gravett, 2016) intended to develop human potential. In the context of this study, I explore the possibilities of ethnomathematics in pre-service mathematics teacher education, and my CHAT analysis will identify factors that inhibit the affordances of contextualised learning.

1.3 MATHEMATICS CURRICULUM AND AFFORDANCES OF ETHNOMATHEMATICS

The scholarly discourse in these concepts focuses the literature on ethnomathematics and its role in the mathematics education curriculum. Intensive review, as elaborated in Chapter 2, enabled me to locate this study within the body of existing literature. The emphasis was on numerous studies that focused on ethnomathematics and how it can be used to teach mathematics. Furthermore, challenges related to the incorporation of ethnomathematics as reported in the literature are discussed. One of the specific aims of the mathematics curriculum, according to SADBE (2011), consider mathematical modeling or contextualisation as

> "…an important focal point of the curriculum. Real life problems should be incorporated into all sections whenever appropriate. Examples used should be realistic and not contrived. Contextual problems should include issues relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible. (p. 8)

This aim acknowledges and promotes ethnomathematical ideas. Thus, the curriculum promotes the ideals of infusing cultural and environmental aspects in contextualising mathematics. The contention is that student teachers should be empowered with knowledge of how they can contextualise mathematics though learners' cultural or everyday contexts. Hence, in this study I intended to explore how student teachers are or can be trained to use ethnomathematical perspectives to contextualise mathematics in their prospective classrooms.

1.4 STUDENT TEACHER PROFESSIONAL DEVELOPMENT

Generally, pre-service teacher education is the focal point towards developing students who seek to be professional teachers. Student teachers' philosophies and knowledge about mathematics are developed during their training in Bachelor of Education degrees. Basically, the professional developments, dispositions, and self-identity of students as teachers develop during their pre-service teacher education. Hence, Steenekamp et al. (2018) maintained that the facilitation of the student teachers' emerging professional identity is paramount in their eventual expertise. According to Sandilos et al. (2018), additional skills to improve instructional approaches are essential towards teachers' professional development. It is in this context that this study sought to explore affordances of ethnomathematics through exposing student teachers to the ethnomathematics intervention workshop, as will be discussed in Chapter 4. Thus, my contention was that the ethnomathematics workshop would offer student teachers experiences wherein opportunities for engaging collaboratively in ethnomathematics learning activities are presented and may enhance their pedagogical knowledge in terms of using various cultural backgrounds in their prospective classrooms, and as well as fostering their self-directed learning attributes. Furthermore, the intention was to also foster learning by providing opportunities for student teachers to learn from the experiences of knowledgeable others in the ethnomathematics field.

1.5 THEORETICAL AND CONCEPTUAL FRAMEWORKS

This section provides an overview of both the theoretical and conceptual frameworks underpinning this study. These frameworks are discussed in detail in Chapter 3.

1.5.1 Theoretical Framework

This study was guided and shaped by the sociocultural theory view that learning cannot be understood and separated from learners' social and cultural worldviews (Vygotsky, 1978). Based on Vygotsky's notion of the Zone of Proximal Development (ZPD hereafter), this study used Warford's (2011) Zone of Proximal Teacher Development (ZPTD hereafter) to scaffold student teachers' professional development towards contextualising mathematics through ethnomathematics approaches. This was achieved through using an ethnomathematics intervention workshop which offered student teachers an opportunity to actively engage and explore mathematics concepts from diverse cultural practices. Furthermore, third-generation

Cultural-Historical Activity Theory (CHAT hereafter), as conceptualised by Engeström (1987) and has its roots in sociocultural theory, was used as a research lens.

1.5.2 Conceptual Framework

The conceptual framework or intermediate theories, as often referred to by Engeström (1987), includes, amongst others, student teacher professional development; pedagogical content knowledge; self-directed learning; embodied, situated, and distributed cognition; indigenous knowledge and ethnomathematics. These constructs were used to establish the study's significance and to locate it within the body of related literature.

1.5.3 Embodied, situated, and distributed cognition

In this study, I argue the affordances of ethnomathematics in the mathematics curriculum from an Embodied, Situated, and Distributed Cognition (ESDC hereafter) perspective (De Beer, 2016). From an ESDC perspective, the physical activities by both teachers and learners can be considered as an extension of the brain (De Beer & Petersen, 2016; Brits et al., 2016; Hardy-Vallée & Payette, 2008; Holvikivi, 2007; Potgieter, 2020). The contention is that learning could be stimulated when student teachers are immersed in different modalities such as the use of cultural artefacts in understanding mathematical concepts. Thus, the integration of ethnomathematics is considered from a learning perspective based on the advances in neuroscience (De Beer & Mentz, 2019).

1.5.4 Pedagogical content knowledge

Pedagogical content knowledge (PCK hereafter) is essential for student teachers to teach mathematics effectively in their prospective classrooms. Shulman (1986) introduced the term pedagogical content knowledge to bring into cognisance a unique kind of teachers' knowledge that is distinctive to teaching and to integrate the subject matter and the knowledge of pedagogy. Shulman (1987) highlighted the need for teachers to not only have knowledge of the content, but also to be able to have pedagogical knowledge which will help them to teach content meaningfully to learners. The focus in PCK is teachers presenting subject matter knowledge in a meaningful way that is accessible for learners (Gravett & De Beer, 2015). The aim of pre-service mathematics teacher education is to prepare mathematics student teachers with strong content knowledge characterised by subject matter knowledge and PCK (Department of Higher Education and Training [DHET], 2011, 2015; Lebeta, 2006; McAuliffe & Lubben, 2013). Teachers' lack of PCK affects the quality of their teaching as well as learners' understanding in the classrooms (Olfos et al., 2014).

1.5.5 Self-directed learning

Knowles (1975) defined Self-Directed Learning (SDL hereafter) as a process where learners or student teachers manage and control their own learning with or without the help of others through identifying learning needs and implementing appropriate learning strategies. It is premised on the ideals that learners are key role players with regard to “what, how, where and when” to learn on their own (O’Shea, 2003, p. 63). In other words, the main aim of SDL is for student teachers to take responsibility for their own learning. According to Williamson (2007), SDL focuses on student teachers’ active participation characterised by taking “the initiative in learning rather than passively waiting to be taught as reactive learners” (p. 67). In essence, SDL advocates a pedagogical transformation which embraces learner-centred learning environments.

1.6 PURPOSE OF THE STUDY

The purpose of the study was to explore the affordances of ethnomathematical perspectives in pre-service mathematics teacher education programmes.

1.7 THE RESEARCH QUESTIONS

This research study sought to answer the following main research question:

1.7.1 What are the affordances of ethnomathematical perspectives in pre-service mathematics teacher education?

To answer the main research question, the following sub-research questions were investigated:

1.7.1.1 What are the teacher educators', expert's and student teachers' understanding and perceptions about ethnomathematical perspectives?

1.7.1.2 How does pre-service mathematics education curriculum prepare student teachers for ethnomathematical perspectives?

1.7.1.3 What are the challenges that both teacher educators and student teachers could face in the incorporation of ethnomathematical perspectives in the mathematics curriculum?

1.7.1.4 What are the guidelines for the effective incorporation of ethnomathematical perspectives in pre-service mathematics teacher education?

1.8 RESEARCH METHODOLOGY

1.8.1 Methodology

This study adopted an instrumental multiple case study design to provide an in-depth understanding of ethnomathematical perspectives in pre-service mathematics teacher education. An instrumental multiple case study focuses on examining particular cases in order to gain insight into an issue or a theory (Creswell, 2013; Cohen et al., 2018; Merriam & Tisdell, 2016). In this study, an instrumental multiple case study was undertaken to promote an understanding of specific issues, in this case, ethnomathematical perspectives. I intended therefore not only to understand the extent to which pre-service teacher education prepares student teachers in ethnomathematics knowledge and skills, but also to scaffold student teachers' professional development towards effective integration of ethnomathematics in their classrooms. By employing the instrumental case study, this study sought to produce a rich and holistic account of an ethnomathematical perspective in pre-service teacher education.

1.8.2 Philosophical orientation/Research paradigm

Guba and Lincoln (1994) described a paradigm as a researcher's fundamental worldview or beliefs which provide guidance to their investigations. As a worldview, it is underpinned by postulations and principles, ideals that are central towards developing comprehension and interpretation of reality (Cohen et al., 2007; Denzin & Lincoln, 2018; Mabotja, 2017). In this regard, I consider it essential to understand the worldview through which knowledge is constructed in order to investigate ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa. As a result, the current study was framed within the interpretivist paradigm, which considers reality as a socially developed, multifaceted and evolving concept (Guba & Lincoln, 1994; Mabotja, 2017). Through this paradigm, I had intended to develop knowledge by interpreting and describing ethnomathematical perspectives as experienced by teacher educators, student teachers and an ethnomathematics expert in pre-service mathematics teacher education at selected universities. This could result in a more nuanced understanding of the phenomenon (in this case teacher training in ethnomathematics) under investigation in the study, as noted by Tuli (2010). In addition, interpretivism was also considered relevant as it focuses on research methods that provide researchers with opportunities to develop in-depth understanding of the phenomena in their inquiries within a distinctive context (Mack, 2010).

1.8.3 Sampling

The population of the study consisted of teacher educators, an ethnomathematics expert and student teachers from three universities offering pre-service (undergraduate) teacher education in South Africa. Purposive sampling, which is “based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned” (Merriam, 2009, p. 77), was adopted as a sampling strategy. As a result, six teacher educators, one ethnomathematics expert and seventeen student teachers were sampled from the three selected universities. The student teachers in pre-service mathematics teacher education generally study mathematics content and method of mathematics modules during their four-year Bachelor of Education programmes. It was therefore hoped that both the teacher educators’, student teachers’, and an ethnomathematics expert’s perceptions would add value on the affordances of ethnomathematical perspectives in pre-service mathematics teacher education.

1.8.4 Data generation instruments

In this study I used the following instruments for the purposes of data collection: semi-structured interviews, a pre-intervention questionnaire, focus group interviews and document analysis.

1.8.4.1 Semi-structured interviews

Semi-structured interviews (Addendum D:8) were conducted with teacher educators and an ethnomathematics expert at the selected universities to obtain detailed information about specific issues of concern (in this case ethnomathematics) (Cohen et al., 2018; Shneiderman & Plaisant, 2006). As a result of the COVID-19 pandemic, some semi-structured interviews were conducted telephonically with other participants. This is explained in greater detail in Chapter 4.

1.8.4.2 Pre-intervention questionnaire

A qualitative questionnaire was used prior to the workshop (only at University C) to explore the student teachers' understanding and preparedness to incorporate ethnomathematics pedagogies in their prospective mathematics classrooms. The questionnaire (Addendum E:11) consisted of open-ended questions derived from the main research question and sub-research questions which guided the research study.

1.8.4.3 Focus group interviews

Focus group interviews (Addendum F:15), which promote participants' interactions with each other and are likely to produce rich data (Creswell, 2003), were conducted with student teachers at University A and University C. By applying focus group interviews, group interactions were considered as a useful way to broaden and diversify the range of responses (Nieuwenhuis, 2007). The focus group interviews were also valuable for enabling student teachers to interact with each other rather than just with the researcher, so that their perceptions supersede the researcher's agenda (Cohen et al., 2007).

1.8.4.4 Document analysis

In addition, document collection and analysis were also be used as part of the data collection. The documents that were collected included the pre-service mathematics education module. In this regard, data are presented in the form of extracts (Addendum J:128-129) which were taken from the pre-service mathematics education modules as I could not include the entire module in the addendum. Teacher educators gave permission to use the module guides. The rationale for document analysis was to focus on the text to classify codes and themes related to ethnomathematical perspectives, as recommended by Creswell (2005). In the context of the intended study, documents were analysed, and the aim was to identify the extent to which ethnomathematical perspectives are integrated within the pre-service mathematics education curriculum.

1.8.5 Data analysis

Merriam (2009) defined data analysis as a process of developing understanding and making sense and meaning out of the collected data. In this study, the verbatim transcribed audio or video data were analysed using Saldaña's (2015) code-to-theory analysis procedure. Saldaña's (2015) coding technique was used to form themes that intertwined with the research questions. As a result, data collected from teacher educators (semi-structured interviews), the ethnomathematics expert (telephonic semi-structured interview), and student teachers (pre-intervention questionnaire, focus group interviews) were divided and presented in the form of pre-set themes based on the research questions. Renner and Taylor-Powell (2003) pointed out that pre-set categories entail starting with a list of themes or categories before you categorise the data and search the data for text that matches the themes.

1.9 CHAT AS THE RESEARCH LENS

Mentz and De Beer (2017) and Rogoff (1995) have made it clear that Cultural-Historical Activity Theory (CHAT) can be applied on three planes, namely, the personal, the interpersonal, and the institutional or community plane. These three planes of applying CHAT as a research lens provide opportunities for CHAT in educational research (De Beer, 2016). The current study applied CHAT on an interpersonal plane level where the focus was on the interactions between various stakeholders (e.g., the teacher educators, and the student teachers) engaging in a collaborative activity. In other words, the activity systems ideally work together to achieve the same goal. As a result, in this study I juxtaposed two activity systems (namely the teaching activities of the teacher educators, and the learning activities of the student teachers) as a unit of analysis (Mentz & De Beer, 2017). The teacher educator was the subject in one, and the student teacher the subject in the other.

To take the analysis a step further, I also used CHAT on the institutional plane where student-teacher professional development on ethnomathematics was considered as the activity system. I relied on this institutional plane analysis to conceptualise the guidelines for student teacher professional development on ethnomathematics pedagogical knowledge and skills as illustrated in Chapter 6.

CHAT provided the framework for describing the integration of ethnomathematical perspectives in pre-service mathematics teacher education, and as a lens showed the tensions and affordances in the activity system. As a result, CHAT enabled representations and influences on how pre-service teacher education develops student teachers to implement/apply ethnomathematical perspectives (object) in the teaching and learning of mathematics.

1.10 RESEARCHER’S ROLE

The researcher’s role in qualitative research is mainly to collect research data from the participants (Creswell, 2011). As a result, my role in the study was to distribute the pre-intervention questionnaire (University C), conduct semi-structured interviews with the teacher educators (from all three universities), and the ethnomathematics expert, and focus group interviews (University A & University C) with student teachers. My role was to engage with the teacher educators, ethnomathematics expert, and student teachers who were the main participants in the study. Furthermore, I also assisted as a facilitator, assisting, and supporting student teachers during the ethnomathematics intervention.

1.11 TRUSTWORTHINESS IN QUALITATIVE RESEARCH

The study achieved rigour through credibility, confirmability, transferability, and dependability (Shenton, 2004). In this section I provide a brief account of these constructs, as detailed explanations are later explained in Chapter 4.

Firstly, credibility was ensured through member checking to afford teacher educators, the ethnomathematics expert and student teachers the opportunity to verify their responses and comment on the findings of the study. In addition, multiple data collection instruments such as semi-structured interviews, a pre-intervention questionnaire, focus groups and document analysis were used to ensure triangulation in this research study. Secondly, confirmability was achieved by providing rich quotes from teacher educators, the ethnomathematics expert, and student teachers in the interpretations and discussions of the results to ensure that the study's findings reflect the experiences and ideas of the participants. Thirdly, transferability was ensured through providing a rich and extensive set of details concerning methodology and the context of the study, as recommended by Li (2004). In addition, a detailed description of the issue under investigation (Shenton, 2004) in the study was provided for comparisons to be made. Lastly, dependability was achieved through multiple data collection instruments which were used to support or contradict the interpretations that were made (Creswell, 2013).

1.12 ETHICAL CONSIDERATIONS

Ethical issues are important to educational researchers who intend to conduct any form of research that involves human beings as their participants (Creswell, 2013). As a result, it is important to be guided by ethical principles in conducting research studies. In this research study, the following ethical principles were adhered to:

1.12.1 Permission

In order to conduct this study, ethical clearance (NWU-00792-18-A2) to conduct research at the selected universities was obtained from the Faculty of Education Sciences Ethics at the North-West University, Potchefstroom Campus (Addendum A:1). Permission to conduct research was granted by the selected universities (Addendum B:2-4). To ensure documents are dealt with ethically, Creswell (2003) recommended that permission to use them be sought from appropriate individuals, in this case the teacher educators who developed the mathematics education modules.

1.12.2 Informed consent

Cohen et al., (2018) stressed that participants should be given enough information pertaining to the study before data collection begins. As a result, the participants in this study were provided with an information letter (Addendum C:5) together with a detailed description of the study and consent forms. Teacher educators, the ethnomathematics expert and student teachers were briefed that participation in the research was voluntary, and that they may withdraw from the research at any stage.

1.12.3 Confidentiality and anonymity

In order to ensure confidentiality, pseudonyms were used to protect the identity of the participants. Since several student teachers participated in focus group interviews, pseudonyms were used during transcription in case students referred to each other by their real names. The student teachers who participated in the ethnomathematics workshop gave permission for the pictures or photographs taken during the workshop to be used without blurring or hiding their faces.

1.12.4 Protecting participants from harm

The data were collected during the COVID-19 pandemic, and I found it necessary to adhere to safety and regulation measures to protect participants from any possible harm that could arise. The participants were further assured that they would not be put in a situation where they might be physically or psychologically harmed because of their participation in or withdrawal from the study (Trochim, 2000).

1.12.5 Ethical issues in data analysis and interpretation

In order to ensure ethics in data analysis, I used pseudonyms to protect the identity of the participants. In interpreting data, I provided an accurate account of the data as emerged during data analysis (Creswell, 2003). Participants were also provided with a copy of the research report to check the accuracy of the data.

1.12.6 Ethical issues in writing up and disseminating research

In ensuring ethical issues in data reporting, I have reported data honestly without changing or altering the findings to support the research questions (Creswell, 2013). In addition, the research report will be made available for qualified scholars, community members, and professionals, as a report should not remain unpublished (Creswell, 2013).

When publishing the results, I signed a declaration that this research study is my own original work and was not previously published or submitted anywhere, as suggested by Creswell (2003). In addition, to avoid plagiarism, I gave proper citations when paraphrasing and quoting scholarly works of the other researchers (Creswell, 2003).

1.13 CONTRIBUTIONS OF THE STUDY

1.13.1 Epistemological contribution

Most research on the integration of ethnomathematics is undertaken at primary school and secondary school levels with little focus on pre-service mathematics teacher education. In this present study, I provide a detailed account of ethnomathematics in pre-service mathematics teacher education with an emphasis on, amongst others, student teachers' preparation and also the guidelines which could be beneficial in informing universities to restructure, where necessary, the existing mathematics education and mathematics methodology courses for the integration of ethnomathematics in pre-service mathematics education. I intended to contribute to the growing body of knowledge on ethnomathematics, particularly in pre-service teacher education.

1.13.2 Methodological contribution

This current research applied CHAT as a research lens at interpersonal and institutional levels respectively. On the one hand, CHAT was applied at instructional level, in particular at instructional level to analyse ethnomathematics in pre-service mathematics teacher education. In this case, two interconnected activity systems were juxtaposed. Teaching (teacher educators) or learning (student teachers) mathematics with or without ethnomathematics were considered as interdependent activity systems. The findings provided insights on how student teachers could be developed or prepared for ethnomathematics.

On the other hand, at the institutional level, ethnomathematics was considered as the subject of the activity system. This provided a possibility to distil effective the guidelines for effective integration of ethnomathematics in pre-service mathematics teacher education. As a result, this research study adds to a growing scholarly discourse on CHAT as a research lens, particularly in the education context.

1.13.3 Practical contribution

The ethnomathematics intervention empowered student-teachers by exposing them to practical ways through which they can integrate ethnomathematics in their prospective classrooms. The research could lead to the provision of pedagogical knowledge for assisting student teachers to effectively use ethnomathematics in their prospective mathematics classrooms.

1.14 OVERVIEW OF THE THESIS

Chapter 1

Chapter 1 provided the introduction and background to the study. This chapter located the problem statement in the existing body of knowledge. The research problem was discussed, together with how the problem was identified. The research questions that assisted in addressing the research problem were outlined.

Chapter 2

The second chapter was a survey of literature related to the current study. The nature of mathematics and state of mathematics in South Africa, particularly with regard to learners' underachievement, was also highlighted. The chapter focused on the intensive work that has already been done with regard to ethnomathematics in mathematics education. It is within this intensive body of knowledge in ethnomathematics that the gap was identified and addressed by the current study.

Chapter 3

The third chapter focuses on the theoretical and conceptual frameworks which framed the research study. It provides the rationale for sociocultural theory, particularly Warford's (2011) ZPTD as a lens to justify the rationale of the study. In addition, CHAT is also discussed and its relevance to this study. Moreover, various intermediate theories (as often referred to by Engeström) such as Embodied, Situated and Distributed Cognition (ESDC), Self-Directed Learning (SDL) and Pedagogical Content Knowledge (PCK) are discussed in relation to ethnomathematics. It is in these constructs that this study found its importance and relevance.

Chapter 4

The fourth chapter outlines the methodology of the study. In this chapter, the research methods and steps taken in describing the affordances of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa are described. The topics that are covered in the design outline include the research paradigm, the case study approach, sample procedure, data collection, data analysis, the ethnomathematics workshop, quality criteria and ethical issues that were adopted by the current study.

Chapter 5

In this chapter I present the findings of the research study. I describe the data generation process and demographic characteristics of the participants. I also describe ethnomathematical perspectives in pre-service mathematics education from teacher educators, an ethnomathematics expert (semi-structured interview), student teachers (a pre-intervention questionnaire, focus group interviews) and document analysis (module course outlines, faculty/school of education calendar as well as the mathematics course materials) perspectives. Therefore, this chapter offers an interpretive and analytical account of the data that was generated and collected during the study. Finally, it analyses the findings from CHAT perspectives.

Chapter 6

This chapter explicates the findings of the current study, which sought to investigate the affordances of ethnomathematics perspectives in pre-service teacher education at selected universities in South Africa. This chapter focuses on answering the research questions which underpinned the study. Limitations and recommendations are also detailed in this chapter.

CHAPTER 1

- BACKGROUND AND CONTEXT OF THE STUDY

CHAPTER 2

- LITERATURE REVIEW

CHAPTER 3

- THEORETICAL AND CONCEPTUAL FRAMEWORKS

CHAPTER 4

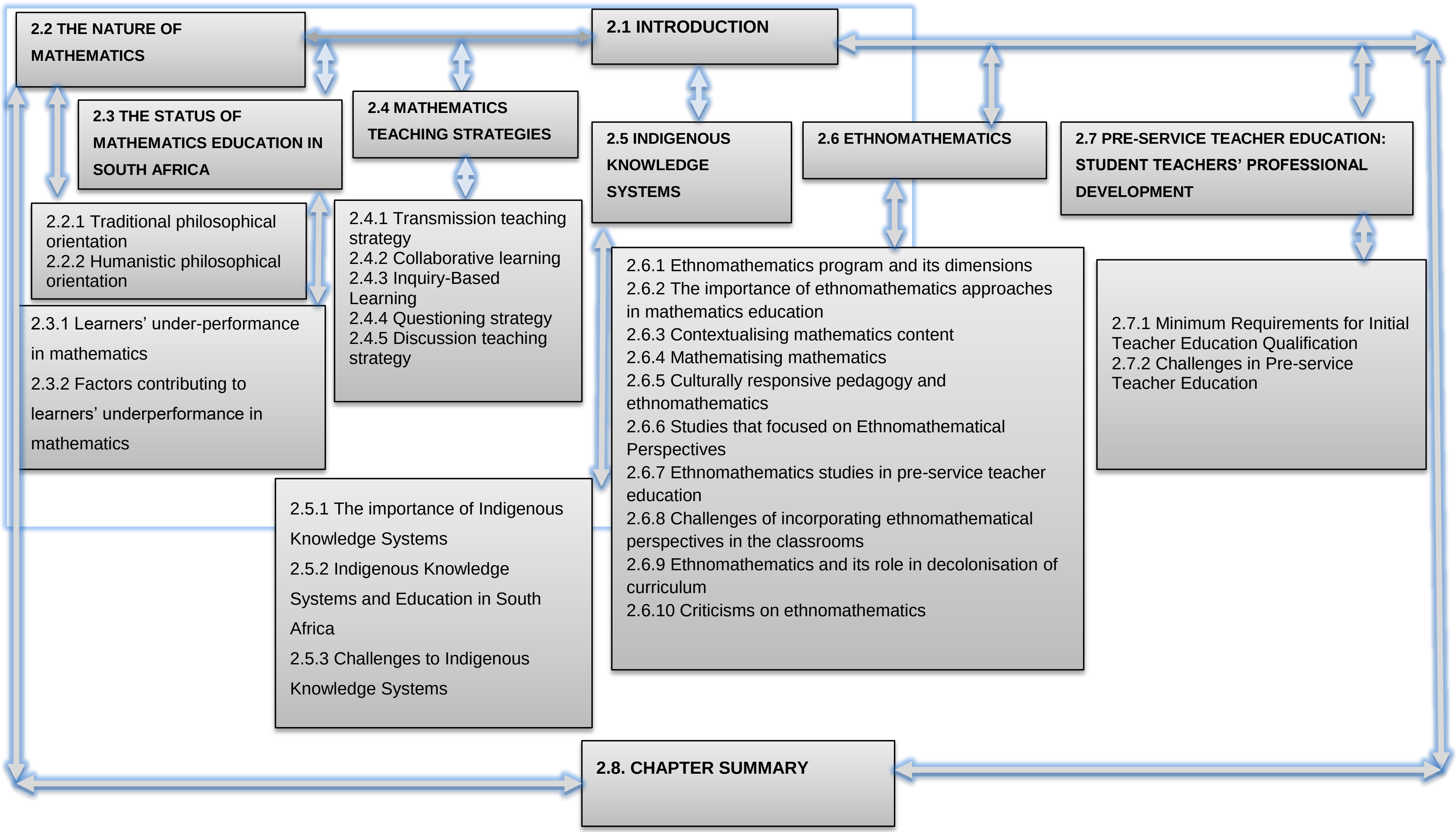
- RESEARCH DESIGN AND RESEARCH METHODOLOGY

CHAPTER 5

- PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

CHAPTER 6

- SUMMARY OF THE MAIN FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION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CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In the previous chapter, the background and the context were clearly elucidated. In this chapter, I provide a comprehensive literature review that was important for the current study. The following constructs are discussed: The nature of mathematics; the status of mathematics performance in South Africa, mathematics teaching strategies, indigenous knowledge systems, ethnomathematics, and pre-service teacher education. These constructs provided this study with importance and relevance.

2.2 THE NATURE OF MATHEMATICS

There are numerous philosophical orientations often used to describe the nature of mathematics, namely; formalism, intuitionism logicism, instrumentalism, Platonism, and Fallibilism (Ernest, 1981, 1995, 2009, 2014). In this study, I focus on two opposing philosophical orientations: traditional and humanistic philosophical orientations (Ernest, 2009). The comprehension of these two opposing philosophical orientations on how mathematics is perceived offers an opportunity to understand their pedagogical implications for mathematics education. There is a general argument in the literature that the pedagogical and research implications emanate from the epistemological discourses concerning the philosophical worldviews about mathematics (Ernest, 2012; Sunzuma, 2019). These authors suggest that how teachers perceive and understand the nature of mathematics will likely influence how they teach it in their classrooms. In this regard, it appears that the nature of mathematics provides a glance towards understanding teachers' mathematics actions in their teaching of mathematics. To expound further, a teacher who perceives mathematics from the traditionalist perspective will teach in accordance with teaching approaches linked with such philosophical orientation, while the humanistic perspective-based teacher will be guided by approaches applicable to the humanistic image. In Table 2-1, I present the two philosophical orientations associated with mathematics.

Table 2-1: Contrasting popular philosophical orientation of Mathematics

Aspect	Traditional Image	Humanistic Image
Approachability	Difficult, forbidding	Approachable and accessible
Human dimension	Cold, neutral, abstract, and impersonal	Human and personal
Social context	Abstract tools applied in advanced societies	Concepts and methods embedded in all of human history and societies
Key elements	Theoretical abstract theories	Practical problem solving and conceptual tools
Applications	Not part of 'real' (pure) mathematics. Applications work by coincidence or because mathematics describes the necessary structure of the universe	Mathematics is grounded in applications providing both inspiration for its concepts and utility through modelling
Procedures and methods	Ultra-rational, strictly following fixed rules	Creative and flexible uses of knowledge to solve problems
Focus	Only interested in right answers and objective facts	Concerned with processes of personal inquiry and understanding
Problem solutions	Only one right answer exists for each task	Problems have multiple solution methods and multiple answers
Source of correctness	Experts have all the answers	Anyone should be able to solve problems and check answers
Ownership	Accessible only to gifted, stereotypically male, minority	Accessible to all and responsible to all

(Adapted from Ernest, 2009, p. 47)

2.2.1 Traditional philosophical orientation

According to Ernest (2009), the traditional philosophical orientation portrays mathematics as inaccessible and beyond the world of ordinary humanity, a subject that is abstract and separated from the world of everyday experience and other areas of study. For Sunzuma (2019), this philosophical orientations is underpinned by Plato's philosophies that advance that mathematics is considered "as a pure form of truth that go beyond cultures and time" (p. 22). In the same vein, Aikenhead (2021) pointed out that the traditional philosophical orientation considers mathematics as hypothetical and abstract in nature. Thus, doing mathematics from the traditional view is perceived as understanding extensive mathematical knowledge and techniques (Raygoza, 2017). Consequently, the traditional philosophical orientation-based classrooms are characterised by an emphasis on repetition, drill, and use of routine procedures without providing learners with opportunities to explore multiple solutions (White-Fredette, 2010). In other words, teachers whose mathematical knowledge is shaped by a traditional philosophical orientation deem mathematics as a difficult, objective, absolute, and abstract discipline which follows a set of fixed rules to solve a task that has only one unique correct answer.

The traditional philosophical orientation considers mathematics knowledge as only accessible to gifted and masculine learners. Furthermore, teachers who embrace the traditional philosophical orientation are likely to exclude learners' cultural background in the teaching and learning of mathematics as they would believe that there is no link between mathematics and culture (Sunzuma, 2019; Sunzuma & Maharaj, 2019). It can be inferred that from a traditionalist point of view, culture has no place in the teaching and learning of mathematics. In my view, the traditional philosophical orientation undermines the contributions made by different cultures in the history and development of mathematics. Consequently, this research study did not align itself with the traditional philosophical orientation as the focus was on the role of culture in mathematics education.

2.2.2 Humanistic philosophical orientation

According to Ernest (2009), the humanistic philosophical orientation considers mathematics as situated within specific historical, geographical, cultural, and social contexts. Ernest further pointed out that the mathematics epistemologies are informed by different cultural practices and developments of humankind throughout history. In the same vein, Hersh (1997) argued that

> Mathematics is like money, war, or religion – not physical, not mental, but social. Dealing with mathematics (or money or religion) is impossible in purely physical terms – inches and pounds – or in purely mental terms – thoughts and emotions, habits, and reflexes. It

> can only be done in social – cultural – historic terms. This isn't controversial. It's [a] fact of life. (p. 248)

The contention is that teaching mathematics without cultural historic terms makes it difficult for learners to understand. Hence, François and Van Kerkhove (2010) argued that academic abstract mathematics cannot be understood or learned in isolation from its cultural environment. Furthermore, the SADBE (2011) aligns itself with the humanistic philosophical orientation, defining mathematics as "a human activity that involves observing, representing, and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves" (p. 8).

In essence, every society in the past and present has its own methods of informal mathematical ideas, and it is these that give rise to, as well as benefitting from, the modern discipline of mathematics. Thus, the humanistic view acknowledges that mathematics concepts and processes are situated within diverse human cultural practices and epistemologies. In this regard, it can be argued that the humanistic philosophical orientation considers mathematics as the mathematics of the people. Contrary to the traditional philosophical orientations which considers mathematics as absolute, the humanistic view acknowledges the fallible, dynamic, and tentative nature of mathematics (Paraide, 2015), which provides evidence that mathematics is linked to the society (Ernest, 2014). It is in the humanistic philosophical orientation where ethnomathematics finds its pedagogical relevance in mathematics education. The inclusion of cultural and historical contexts in mathematics classrooms enable all learners to "feel a pride in the contributions of their ancestors as well as an ownership of mathematics" (Ernest, 2009, p. 56).

The humanistic philosophical orientation, unlike the traditional philosophical orientation, focuses on developing learners' creativity in problem-solving processes (Ernest, 2009). In this philosophical orientation, learners are encouraged to use a variety of mathematical methods and procedures to find solutions. Thus, teachers who embrace and promote the humanistic philosophical orientation in their classrooms are of the opinion that every learner has the potential to construct mathematics knowledge. They further strive to create a participatory learner-centred environment where learners share ideas with each other. Furthermore, the humanistic philosophical orientation focuses on the learners' thought process instead of following a set of determined methods to solve a task.

The humanistic philosophical orientation has been adopted in this study as "it acknowledges that only is academic mathematics utilized in a variety of applied practices, but also that both ethnomathematics … and school mathematics have been appropriated and recontextualized in academic mathematical practices" (Ernest, 2009, p. 54). In other words, calls for the integration of ethnomathematics pedagogies have been influenced by the paradigm shift from a traditional to a humanistic philosophical orientation which advocates the contributions of various cultures in mathematics. Hence, D'Ambrosio (2016) highlighted that one of the main aims of introducing ethnomathematics was to "demystify school mathematics as a final, permanent, absolute, unique form of knowledge" (p. 1).

2.3 THE STATUS OF MATHEMATICS PERFORMANCE IN SOUTH AFRICA

Mathematics, an important school subject, is a fundamental socio-economic development of every society (Mapaire, 2016; Van der Walt et al., 2019) and is considered by Mentz and de Beer (2019) as "a sine qua non for [universal] competitiveness" (p. 50). The contention is that the essence of mathematics is multifarious in the sense that no field of study can avoid its role (Abdurrahman et al., 2015). Thus, mathematics can be viewed as a foundation across many sectors in a society. It is also regarded as one of the mandatory requirements in careers such as health, engineering, science, and commerce, just to mention a few. The significance of mathematics implies that its teaching and learning need to be prioritised for learners to globally compete and contribute to the development of their countries.

Furthermore, the CAPS curriculum recognises the importance of mathematics, as evident in the specific aims. It states that the "teaching and learning of mathematics aim to develop

- a critical awareness of how mathematical relationships are used in social, environmental, cultural, and economic relations
- confidence and competence to deal with any mathematical situation without being hindered by a fear of Mathematics
- an appreciation for the beauty and elegance of Mathematics
- a spirit of curiosity and a love for Mathematics
- recognition that Mathematics is a creative part of human activity
- deep conceptual understandings in order to make sense of Mathematics
- acquisition of specific knowledge and skills necessary for:

    - ✓ the application of Mathematics to physical, social, and mathematical problems
    - ✓ the study of related subject matter (e.g., other subjects)
    - ✓ further study in Mathematics." (SADBE, 2011, p. 8)

The above specific aims do not only seek to raise learners' awareness of the role of mathematics but also their confidence in mathematics. The aims provide evidence that learners should have confidence in learning mathematics. Furthermore, they seek to encourage learners to love mathematics and pursue studies related to this field of study. The mathematics classrooms should be centres of curiosity where learners become actively involved in the construction of mathematical knowledge. In other words, it is essential that learners learn mathematics with understanding. The contention is that mathematics teachers should pay attention to these specific aims and teach learners accordingly. By so doing, learners may start to acknowledge and see the beauty of mathematics and their attitude towards mathematics may become strengthened.

Furthermore, the CAPS mathematics curriculum outlines that learners should:

- develop the correct use of the language of Mathematics
- develop number vocabulary, number concept and calculation and application skills
- learn to listen, communicate, think, reason logically and apply the mathematical knowledge gained
- learn to investigate, analyse, represent, and interpret information
- learn to pose and solve problems
- build an awareness of the important role that Mathematics plays in real life situations including the personal development of the learner" (SADBE, 2011, pp. 8-9).

The above-mentioned specific aims suggest that the teachers should develop learners' mathematical vocabulary and language which will help them to communicate mathematical ideas in problem solving. Regardless of the significance of mathematics outlined in specific aims and skills, learners' underperformance in this essential knowledge area is of serious concern, as discussed in the following sub-sections.

2.3.1 Learners' underperformance in mathematics

International assessment bodies, such as the Trends in International Mathematics and Science Study (TIMSS), are often used to assess mathematics and science amongst learners in Grades 4, 8, and 9 around the world. TIMSS is a recognised international assessment study designed to measure the effectiveness of an education system within a country in relation to mathematics and science (Reddy et al., 2020). In South Africa, over the past decades, Howie (1997, 2001) studied South African learners' performance in 1995 and 1999 as reflected in the TIMSS reports and noted that their performance was not satisfactory. South African learners' performance in these assessments was poor when comparing it to their counterparts in other countries such as Singapore. Likewise, the 2011 and 2015 TIMSS reports had shown again that both Grade 4 and Grade 8 learners' performance in mathematics ranked second last out of 48 participating countries (Mullis et al., 2012; Reddy et al., 2016). These TIMSS results reflect the concern "that

South Africa has, for many years, languished at the bottom of the list when it comes to the performance of school learners in science and mathematics" (de Beer, 2016, p. 1).

The above-cited TIMSS reports further suggest that learners in primary school lack basic mathematics concepts and skills. Thus, learners do not have sufficient mathematical knowledge and understanding as assessed against other countries. They struggle to comprehend mathematics in their foundational years. This state of performance has direct implications for learners' success or failure in their later grades. The knowledge they acquire would become important in their next grades. When learners fail to achieve at foundation or intermediate phase, their prior knowledge is underdeveloped, which will affect their ability to make connections in understanding new concepts.

Furthermore, at a national level, SADBE depends on the National Senior Certificate (NSC) examinations to primarily assess learners' achievement of expected learning outcomes at the end of 12 years of schooling. According to SADBE (2021), the NSC examinations have, over the years, been used as an instrumental sign of the education system's performance. Thus, the effectiveness or ineffectiveness of basic education is measured by the NSC examinations. Hence, SADBE (2021) has pointed out that, "It provides valuable data to education planners, institutional role players and decision …[to] improve the quality of basic education" (p. 11). In this research study, I focused on the NSC mathematics examinations for Grade 12 learners in mathematics over a five-year period (2016-2020) (see Table 2-2 below).

Table 2-2: Candidates' performance in mathematics from 2016 to 2020

Subject	Year	Wrote	Achieved 30% & above	% Achieved
Mathematics	2020	233 315	125 526	**53,8**
	2019	222 034	121 179	**54,6**
	2018	233 858	135 638	**58,0**
	2017	245 103	127 197	**51,9**
	2016	265 810	135 958	**51,5**

(Adopted from SADBE, 2021a, p. 57)

Table 2-2 shows that the average Grade 12 learners' performance in 2016 was 51,5%. This shows that almost half of the Grade 12 learners (48,5%) who wrote the 2016 mathematics examination underperformed. The table further shows an increase from 2016 (with 51,5%) to 2018 (with 58,0%). Thus, over a three-year period (2016-2018) there was an increase of 6,5% in mathematics examination results. However, there is evidence of Grade 12 learners' disappointing decline from the 58% achieved in 2018 to 53,8% in the 2020 examinations. These mathematics results over the past years reveal learners' lack of understanding of basic mathematics concepts. Hence, SADBE (2016) national diagnostic report for 2015 NSC examination revealed that "learners struggled with Mathematics in Grades 11 and 12 because they could not do the basic mathematics of Grade 8, 9 and 10" (p. 151).

Furthermore, the SADBE report highlighted the negative impact of COVID-19 on the 2020 national examinations. This was evident in the comment that the "disruptions caused by the COVID-19 pandemic have clearly affected performance in the Grade 12 examinations, and relative performance across subjects" (SADBE, 2021b, p. 20). Regardless of COVID-19, the overall Grade 12 learners' performance in the five-year period 2016-2020 reveals that over 40% of learners underperformed in mathematics examinations. This underperformance further affirms that "many learners in South Africa do not sufficiently master the mathematics knowledge and skills required in problem solving" (Maree et al., 2006, p. 229).

Table 2-2 further indicates a decline in the number of Grade 12 mathematics learners in a five-year period (2016-2020). This decline raises concerns over learners' participation in STEM education (Wilson, & Mack, 2014). Among the possible explanations for these concerns is that a decline in number of learners suggests that fewer learners will be admitted into STEM careers. Furthermore, it shows that learners are losing interest in this gateway subject. Contrary to the specific mathematics aims mentioned earlier, learners' motivation and confidence to learn mathematics concepts may be weakened by anxiety and fear due to the traditional philosophical orientation of mathematics. They perceive mathematics as a difficult subject and therefore pursue mathematical literacy which is often considered to be less difficult. As a result of learners' underachievement in mathematics and other subjects, SADBE has over the last few years devoted efforts to focus on early childhood development (ECD) and the General Education and Training (GET) bands as they are the determinant of learners' performance in NSC examinations (SADBE, 2021b).

While NSC examinations focus on Grade 12, SADBE introduced the Annual National Assessments (ANA) in 2012 to monitor lower grades' (Grades 1-9) performance in English and mathematics. Although discontinued in 2015, ANA provided evidence that learners have not mastered basic algebraic skills and were unfamiliar with mathematical terminologies and properties (SADBE, 2012, 2013 & 2014). Among the plausible reasons for these unsatisfactory results is that learners have not yet developed sufficient number conceptions and the appropriate mathematics language. Lessons from ANA suggested the necessity to prioritise mathematics in intermediate, foundation, and senior phases. Hence, Adler and Pillay (2017) have pointed out that the Basic Education system is characterised by a lack of quality teaching and learning in early grades. This requires urgent attention since mathematics difficulties and misconceptions ignored at early grades of schooling could make it difficult for learners to understand mathematics in the later grades (Mabotja, 2017; Machaba, 2013; Makgakga, 2012). In this regard, it can be argued that the foundational knowledge upon which learners build on from early grades, plays an important role towards their performance in NSC mathematics examinations.

2.3.2 Factors contributing to learners' underperformance in mathematics

Learners' underperformance in mathematics is often attributed to a multitude of challenges. For example, researchers over the past decades noted factors such as teachers' inadequate PCK, insufficient resources, socio-economic factors, and the curriculum as some of the challenges which contribute to underachievement (Adler & Pillay, 2017; Gitaari et al., 2013; Letsoalo et al., 2018; Maree, 2010; Mbugua et al., 2012). These factors suggest that both in school- and outside school-related factors have a significant impact on learners' mathematics performance.

The Centre for Development and Enterprise's (CDE) report (2014) lamented teachers' lack of PCK and inadequate subject content knowledge as a major contributing factor. Thus, the report reflects teachers are inadequately prepared to teach mathematics. PCK generally refers to a special blending of teachers' knowledge about the subject and pedagogies to make it accessible and meaningful to learners (Berry et al., 2016; Shulman, 1987) (discussed in Chapter 3). Teachers' lack of pedagogical knowledge and skills is often reflected in learners' underperformance in both national and international assessments. The contention is that developing teachers' PCK may improve learners' performance (Pournara et al., 2015). As a result, it is essential for mathematics teacher education programmes to improve and develop student teachers' mathematics knowledge (Taylor & Taylor, 2013) as well as their pedagogical knowledge. Thus, student teachers should not only develop subject content knowledge but also be able to use different teaching strategies to present mathematics topics meaningfully. It could be argued that student teachers should be empowered with pedagogical knowledge and skills that will promote effective learning environments. This research study focused on pre-service teacher education with regard to how student teachers' PCK could be developed through ethnomathematical perspectives.

Moreover, research has shown that socio-economic factors contribute to learners' underperformance in mathematics (Kiwanuka et al., 2015; Makgato, 2007; Reddy et al., 2019; SADBE, 2021b; Valero et al., 2015, Visser et al., 2015). The SADBE (2021b) noted that "the persistence of socioeconomic divide in the South African schooling system continues to engrave negative trends of learner performance in disadvantaged communities" (p. 25). This affirms that learners from higher socio-economic backgrounds are likely to perform better than their counterparts from lower socio-economic backgrounds (Kiwanuka et al., 2015). With South Africa being regarded as one of the most unequal countries in the world (Statistics South Africa, 2019), the challenges imposed by socio-economic factors are likely to continue affecting learners from disadvantaged communities, which involves a large percentage of learners in South Africa.

In addition, other studies have found that a lack of teaching and learning aids contributes to learners' mathematics performance (Mji & Makgato, 2006; Varaidzai et al., 2020). Thus, the accessibility of teaching resources such as textbooks and mathematics virtual technology resources can impact positively on the learners' performance in mathematics. A lack of learning resources is often an issue in rural disadvantaged public schools in South Africa, which are attended by the majority of learners. Most private schools do not experience a lack of resources as compared to public schools. A lack of resources has dire consequences, not only contributing to learners' underperformance but to a loss of interest in mathematics (Markus & Mhlolo, 2018).

Another factor linked to learners' underperformance in mathematics is negative attitude. For instance, Tshabalala and Ncube (2016) noted that the majority of learners perceive mathematics as a naturally difficult subject. This perception advance the traditionalist philosophical orientation that mathematics is only for gifted learners (as discussed in 2.2.1), which does not help learners to develop a positive attitude to mathematics. Learners who do not have positive attitude towards mathematics may not have the interest and motivation required in the learning processes. Hence, Botty et al. (2015) argued that learners who have a positive attitude toward mathematics perform better. The contention is that teachers need to pay attention to learners' attitude and guide them towards effective learning of mathematics.

Another reason for underperformance that is relevant to this study is that mathematics is often not contextualised in learners' everyday contexts (Van der Walt et al., 2019) and, as a result learners may perceive it as unrelated to their daily lives. Teaching mathematics in a way that is divorced from learners' daily cultural experiences appears to affect their performance negatively (Fouze & Amit, 2017; Gay, 2002; Gerdes, 2009). Thus, the CAPS curriculum is often lamented for failing to provide guidance on how IKS or ethnomathematics can be used in classrooms (Naidoo, 2010) to contextualise mathematics. Learners enter the classroom with knowledge and understanding shaped by their sociocultural background, which may be useful in learning mathematics (Harding-DeKam, 2014; Van der Walt et al., 2019). One can ask the question whether student teachers are sufficiently prepared/trained during their teacher education programmes (such as the BEd degree – developed by teacher educators) as well as whether professional development programmes (developed and presented by departmental officials) for in-service teachers focus on the teachers' PCK on ethnomathematics epistemologies.

Learners' underperformance in mathematics is well-understood and research should now focus on exploring possible solutions. Alternative pedagogical or instructional approaches such as ethnomathematical perspectives (D'Ambrosio & Rosa, 2017; Jagals & Van der Walt, 2016; Sharma & Orey, 2017) have been proposed (discussed in section 2.6). The integration of ethnomathematical perspectives in mathematics education appears to have long-term benefits for learners' mathematical meaning making in mathematics and their achievements (Achor et al., 2009; Rosa & Orey, 2016). Rosa (2010) argued in a similar vein that a lack of cultural coherence in the curriculum contributes to learners' mathematics underachievement. Mathematics education, particularly mathematics teaching and learning in South Africa, has historically lacked cultural relevance for learners, contributing to alarming underachievement in mathematics.

2.4 MATHEMATICS TEACHING STRATEGIES

Teaching strategies are generally referred to as strategies which teachers apply in the learning environment to help learners access the knowledge in order to achieve the learning outcomes (Amos et al., 2015; Arends et al., 2017). It is critical that teachers implement teaching strategies in the classroom that accommodate and promote diverse learning needs. The strategies should enable students to establish connections between their own sociocultural experiences and the mathematical concepts they learn at school. The choice of teaching strategies has an impact on learners' understanding and achievement of learning outcomes in mathematics. Teachers often use diverse pedagogies relevant to specific mathematics concepts or topics (Makgakga, 2011). In other words, each mathematics content requires a specific teaching strategy. As a result, teachers must understand that teaching strategies in mathematics learning environments are not one-size-fits-all.

Teachers' teaching strategies should assist learners in developing not only mathematical knowledge, but also the ability to communicate and utilise that knowledge in a variety of problem-solving contexts. While a variety of teaching strategies such as discussion, problem solving, direct teaching, investigations, and collaborative learning exists, some of the strategies may not necessarily have an influence on learners' understanding and performance (Mosimege &

Winnaar, 2021). Thus, while other strategies could assist learners to develop mathematical understanding, others may not. Some of the commonly used teaching strategies include transmission strategy, collaborative learning, inquiry-based learning, discussion, and questioning, as discussed in the following sub-sections.

2.4.1 Transmission teaching strategy

The transmission teaching strategy (telling method/traditional method) generally refers to a teacher-centred teaching strategy characterised by the teacher presenting mathematics concepts and procedures required to determine the solution where learners passively acquire the knowledge and procedures as presented (Ardeleanu, 2019; Chapko & Buchko, 2004; Makgakga, 2012). This strategy assumes that mathematics teachers are regarded as the only source of information in the teaching and learning processes. In other words, they are regarded as all-knowing and learners as empty vessels which should be filled with knowledge—a concept Piaget (1977) conceptualised as *tabula rasa*. The argument is that mathematics knowledge is passed down from teachers to learners. A classroom dominated by the transmission teaching strategy is often characterised by learners learning by copying mathematical notes and examples written on the chalkboard by teachers.

Furthermore, this strategy is often associated with memorisation of mathematical facts and procedures, with learners not encouraged to develop questioning and reasoning skills, or conceptual understanding (Furguson, 2010). Bature and Bature (2009) considered this as outdated because mathematics is mainly taught and learned without meaningful understanding. Unfortunately, many mathematics classrooms are widely characterised by the transmission teaching strategy where learners are exposed to rote learning in preparation for their examinations (Alex & Mammen, 2014; Ardeleanu, 2019; Masilo, 2018; Siyepu & Mtonjeni, 2014). The contention is that the use of the transmission teaching strategy is effective in preparing learners for summative assessments.

2.4.2 Collaborative learning

Collaborative learning (or cooperative learning) is characterised by a learning environment where knowledge is shared amongst learners to find solutions and deepen their understanding of what they are learning (Mabotja, 2017; Olanrewaju, 2019). It is essential for learners' growth of mathematical understanding (Mabotja, 2017; Mabotja et al., 2018; Rankweteke, 2020). In this teaching strategy, learners are urged to collaborate with each other by sharing knowledge, problem solving strategies, and resources in order to succeed. This provides learners with opportunities to explain, justify, and also see the limitations of their ideas. Thus, learners could begin to see their ideas from a different perspective. They also learn to respect each individual contribution. In this learning environment, the teacher acts as facilitator rather than authority as happens in a transmission teaching strategy. The essence of collaborative learning is that learners succeed as a team.

Although collaborative learning puts more emphasis on teamwork, it does not impede learners from working individually (Pillay & Maharaj, 2011). Thus, it will help learners to develop the perception that their success in mathematics is strongly linked to each individual contribution in a collaborative learning environment. It helps learners to be responsible and accountable for the teamwork. In this regard, the teacher can randomly select any learner from the group to explain their ideas and strategies to the whole class. The collaborative teaching strategy promotes learners' activity participation in their learning process. By so doing, learners will develop confidence that they are able to represent or lead the discussion for group contributions.

2.4.3 Inquiry-Based Learning

Love et al. (2015) defined Inquiry-Based Learning (IBL hereafter) as "a method of teaching that engages students in sense-making activities. Rather than showing facts or a clear, smooth path to a solution, the instructor guides students via well-crafted problems through an adventure in concept discovery and application" (p. 746). IBL promotes learners' cognitive abilities which are essential in problem solving contexts (Masilo, 2018; Maxwell et al., 2015). According to Sockalingam et al. (2011), when learners actively engage with a problem, they develop new knowledge and deepen their current understanding. As a result, the teacher's role in IBL is primarily to promote discussion and provide learners with guidance when necessary. Although the teachers can provide guidance, they do not necessarily point learners to the solution (Calder, 2013). As opposed to the transmission mode teaching strategy characterised by rigid presentations of facts, in IBL the teachers encourage learners to think about the problem and possible ways to approach it. Thus, emphasis is on learners establishing the connection between ideas rather than passively receiving knowledge from their teachers.

Regardless of the importance of IBL in learning environments, many South African teachers continue to experience challenges regarding its implementation. For example, Ramnarain and Hlatswayo (2018) found that teachers are concerned "the South African curriculum [is] heavily content-laden, with a multitude of topics that are required to be covered in a limited period of time" (p. 6). Their contention is that that more time is required for teachers to implement learner-centred IBL in the teaching and learning environment. This challenge further implies that teachers focus more on teacher-centred than learner-centred teaching strategies with the intention of circumventing the issue of time.

2.4.4 Questioning strategy

The questioning strategy is the one the teacher uses to elicit learners' mathematical understanding (Dahal, 2022; Mabotja et al, 2018; McCarthy et al., 2016). In other words, it is often used by teachers to develop an understanding of what learners know or do not know about the mathematics concepts they are teaching. Thus, the kind of mathematical knowledge learners develop and communicate is dependent upon teachers' questioning (Dahal et al., 2019). Furthermore, through the questioning strategy, teachers are able to identify misconceptions and enhance learners' reasoning (Mabotja, 2017; Mabotja et al., 2018). When teachers are aware of learners' misconceptions, they may apply appropriate measures to correct them.

It is necessary for mathematics teachers to develop an in-depth knowledge of questioning as a teaching strategy to enhance learners' understanding in mathematics (Dahal et al., 2019). As a result, teachers will know what kind of questions to ask and when to ask them. It develops learners' confidence and skills as they explain their thinking processes. As a result, teachers need to vary the questions they ask learners in the learning environment. Within the context of South African classrooms, questions should take into consideration Bloom's levels of taxonomy which often inform assessments.

2.4.5 Discussion teaching strategy

The discussion teaching strategy refers to a strategy the teacher uses to guide the learners to learn amongst themselves (Makgakga, 2012). In this learner-centred strategy, the teacher often teaches mathematics concepts by actively involving the learners in the learning process through questioning. Learners' responses not only shape teachers' questions but shape the mathematical discourse (National Council of Teachers of Mathematics [NCTM hereafter], 2013). As a result, it is essential that the teacher pays equal attention to both correct and incorrect responses given by the learners. By so doing, the teacher becomes equipped to respond appropriately and use learners' responses to develop their conceptual understanding in mathematics.

In addition, learners' responses also inform the teacher's feedback in the learning processes. Consequently, the learners develop confidence in articulating their ideas, knowing that the teacher appreciates and acknowledges their contributions. Equally important, when the teacher does not take into consideration contributions from the learners, it discourages them from sharing their ideas during the discussion. The ideas they bring to their learning environment are valued and used to guide the feedback. In essence, the discussion provides learners with opportunities to re-examine their initial ideas and build upon them.

The above-mentioned teaching strategies are essential and commonly used in mathematics classrooms. In addition, some of the learner-centred strategies such as collaborative learning, inquiry-based learning, and questioning provide opportunities for integrating ethnomathematics approach, as discussed in the next sections.

2.5 INDIGENOUS KNOWLEDGE SYSTEMS

Indigenous Knowledge Systems (IKS hereafter) has widely been researched. However, there is no common or universal definition of IKS. Thus, different people define IKS differently in relation to how they apply or use it in their context. For example, Tella (2007) defined IKS as “the complex set of knowledge, skills and technologies existing and developed around specific conditions of populations and communities to a particular geographic area” (p. 186). Similarly, Onwu and Mosimege (2004) viewed IKS as a comprehensive knowledge that includes technologies and practices that have been and are still applied by indigenous and local people in their everyday living. Such knowledge is understood to be developed by people from specific cultures by means of experiences, interactions and profound comprehension of their socio-environmental contexts (Rankoana, 2017; Warren, 1996). According to Tella (2007), IKS provide foundations for numerous community activities such as “agriculture, food preparation, health care, education and training” (p. 186). For McClure (1989), IKS are “learned ways of knowing and … [understanding how] … the world … [which] evolved from years of experience and trial-and-error problem solving by indigenous people working in their environments and drawing upon resources they have at hand for sustainable living” (p. 1).

The above definitions show that IKS is based on a system of cultural ideas or practices that are unique to a specific culture and have evolved from generation to generation. In other words, IKS could be regarded as an ecologically-based approach. Thus, the environment plays an essential role in shaping the experiences of the local people. Cronje (2015) posits that it is rooted in historical and cultural contexts and is as a result of human activities connected to everyday life. These views of IKS suggest that IKS is premised in African epistemologies and thinking which have evolved over many years. Based on African philosophical thinking and cultural or social practices, this research study focus on their affordances in pre-service mathematics teacher education. The contention was that mathematical ideas and knowledge situated within cultural practices should be used to contextualise mathematics.

2.5.1 The importance of Indigenous Knowledge Systems

Yaboub's (n.d) report on Indigenous Knowledge identifies two basic reasons why IKS is essential. Firstly, IKS contributes to local empowerment and development. The contention is that IKS characterised by valid and valuable knowledge to address problems of sustainable development and the environment (Cronje, 2015). Yaboub (n.d) posits that the application of IKS "in research and management plans gives it legitimacy and credibility in the eyes of both local people and outside scientists, increasing cultural pride and thus motivation to solve local problems with local ingenuity and resources" (p. 10). Noyoo (2007) argues that IKS can be an alternative to countries that are overly dependent on modern technologies in their quest to raise the living conditions of its local communities. This means that IKS can advance understanding of local conditions and provide relevant strategies towards creating solutions that will help local communities. Hence, Tella (2007) underscores that IKS contributes towards understanding developmental issues.

Secondly, IKS provides cultural groups with knowledge about "the local environment and how to effectively manage …natural resources" (Yaboub, (n.d.), p. 10). This means that IKS acknowledge that indigenous people have, over decades, maintained their local environments without destroying their ecosystem (Matowanyika, 1994). The contention is that IKS can provide a framework with alternative ways of maintaining ecologies. Learning from IKS offers opportunities for in-depth insight into community aspects and possible solutions towards developing such communities (Yaboub, n.d.).

2.5.2 Indigenous Knowledge Systems in the South African curriculum

In the last decade, numerous researchers have promoted the integration of IKS in the mathematics, science, and technology curriculum (Brits et al., 2016; Chahine, 2013, 2014, 2016; Chahine et al., 2013; Jagals & Van der Walt, 2016; Madimabe et al., 2020). The CAPS curriculum promotes the "valuing [of] indigenous knowledge systems" in the education system (SADBE, 2011, p. 5). In the same vein, Fien (2010) argued that the use of IKS may provide opportunities for learners to acknowledge their sociocultural contexts in the learning processes. The contention is that IKS advocates for inclusivity of local knowledge in mainstream knowledge domains. This means that it seeks to acknowledge and affirm the local knowledge of the formerly colonised cultural groups.

According to Chahine (2016), the integration of IKS will equip learners with comprehensive knowledge which embraces mathematics concepts situated within sociocultural contexts. Koehler (2017), in describing the critical role of IKS in the formal education system, argued that learners will struggle to link school learning experiences and sociocultural contexts when IKS is not given a place in the mainstream curriculum. Furthermore, the integration of IKS can promote education that values learners' prior knowledge (Hamilton-Ekeke & Dorgu, 2015). Similarly,

> The inclusion of mathematical ideas found in different cultures around the world, the acknowledgment of contributions that individuals from diverse cultures have made to mathematical understanding, the recognition and identification of diverse practices of a mathematical nature in varied cultural procedural contexts, and the link between academic mathematics and student experiences should become a central aspect to a complete study of mathematics. (Orey & Rosa, 2007, p. 141)

These views suggest that IKS embraces multiple ways of knowing which learners may use to learn mathematics.

There are many contexts that provide opportunities for integrating IKS in mathematics, as evident in the literature. For example, traditional games, buildings, dance, beadwork, weaving and other practices (Chahine, 2016; Jagals & Van der Walt, 2016; Machaba & Dhlamini, 2021; Madusise, 2022; Moloi, 2020). Thus, it appears there are diverse cultural practices which could be used as resources in mathematics classrooms. Such practices in mathematics education are considered as ethnomathematics approaches. For Jagals and Van der Walt (2016), ethnomathematics approaches are better understood as an expression of indigenous knowledge. According to Seroto (2012),

> Ethnomathematics may be regarded as one component of an indigenous knowledge system, focusing on the mathematical aspect of those systems (i.e., mathematics which is practised among identifiable cultural groups such as labour groups, children of certain age group, national-tribal societies, professional class and rural communities). (p. 39)

I discuss these variety of ways of integrating IKS within the context of ethnomathematics in the next section which focuses on ethnomathematics and its implications in mathematics education.

2.5.3 Challenges to Indigenous Knowledge Systems

Regardless of the importance of IKS, there are numerous challenges associated with it. These include, amongst others, that IKS is easily overlooked and excluded, and inadequate documentation of local practices (Knopf, 2015; Yaboub, n.d). With regard to being overlooked and excluded, colonialism has previously "imposed themselves on the colonised as the only legitimate knowledge to the exclusion of the knowledge systems of the colonised" (Murove, 2018, p. 160). Thus, IKS was excluded on the basis that it was considered as anecdotal, non-quantitative, without method, and unscientific (Knopf, 2015). This form of exclusion advances the lack of recognition, understanding and use of IKS amongst societies.

Another challenge to IKS is inadequate documentation of local practices. According to Yaboub (s.a), IKS is generally communicated through "word of mouth rather than written form" which can lead to its extinction (p. 15). Sithole (2006) has also pointed out that that African libraries and information centres are faced with a plethora of challenges concerning IKS documentation. The contention is that adequate documentation of IKS will result in preservation and transmission of knowledge bases engrained within cultural backgrounds and customs from one generation to the next.

2.6 ETHNOMATHEMATICS

The definition of ethnomathematics or its conceptualisation in any standard dictionary has yet to emerge. As a result, more than one definition exists in the literature. From research on ethnomathematics, different researchers who have attempted to conceptualise ethnomathematics can be distinguished (Table 2-3).

Table 2-3: Definitions of Ethnomathematics

Author(s)	**Definition or description of ethnomathematics**
Ubiratan D'Ambrosio (1985)	"The mathematics which is practiced among identifiable cultural groups" (p. 45).
Ascher and Ascher (1986)	"The study of mathematical ideas of non-literate peoples" (p. 122).
Gerdes (1986)	"recognizing the mathematical character" and identifying the "frozen mathematics" (p. 10).
Hammond (2009)	"The study of the culturally-related aspects of mathematics; it deals with the comparative study of mathematics of different human cultures, especially in regard to how mathematics has shaped, and in turn been shaped by, the values and beliefs of groups of people" (p. 11).
Rosa and Orey (2011)	The study of "cultural aspects of mathematics. It presents mathematical concepts of the school curriculum in a way in which these concepts are related to the students' cultural and daily experiences" (p. 32).

While acknowledging different researchers' contributions from the above table (and those excluded in the research study) towards defining ethnomathematics, the origin of ethnomathematics as a concept in mathematics education research is often attributed to Ubiratan D'Ambrosio, a mathematician and educator from Brazil, who is often referred to as the intellectual father of ethnomathematics. According to D'Ambrosio (1985), ethnomathematics is defined as "mathematics which is practiced among identifiable cultural groups" (p. 45). The main premise for ethnomathematics is on the mathematical ideas and activities such as counting, drawing, inferring, ordering, sorting, measuring, and reasoning which are evident in people's daily living. D'Ambrosio's definition suggest that ethnomathematics examines mathematical ideas and concepts found from different cultural practices across the world.

D'Ambrosio (1993, 2018, 2020) went further to shed more light on ethnomathematics by making references to *ethno, mathema*, and *tics* as Greek roots underpinning the concept. In this regard, D'Ambrosio argued ethnomathematics as a manner by which

> members of specific cultures (*ethno*) developed, over history, the measuring, calculating, inferring, comparing, and classifying techniques and ideas (*tics*) that allow them to model natural and social environments and contexts in order to explain and understand these phenomena (*mathema*). (Rosa & Orey, 2016, p. 11)

In Powell and Frankenstein's (1997) view,

> D'Ambrosio's broader view of ethnomathematics accounts for the dialectical transformation of knowledge within and among societies. Moreover, his epistemology is coherent with Freire's (1970) in that D'Ambrosio views mathematical knowledge as dynamic and the result of human activity, not static and ordained. (p. 8)

Hence, Cimen (2014) underscored that ethnomathematics is not only rooted but also clearly practised, presented by different cultural groups. While numerous authors differ in terms of defining ethnomathematics, they agree that mathematics exists and is situated in sociocultural practices.

From Hammond's (2000) viewpoint, Ascher and Ascher's definition provided a "concrete example of ethnocentrism and an encouragement of the idea that proper mathematics is a notion defined only by the literate peoples" (p. 8). Hammond's contention illustrate the restrictive nature of understanding and implications of ethnomathematics. To counter such restrictive views of ethnomathematics, Hammond went further to propose ethnomathematics as underpinned by how human cultures have contributed to the development of mathematics. In this research study I was drawn to Hammond's (2000) and Rosa and Orey's (2011) definitions of ethnomathematics as the study of mathematical ideas and skills situated within various cultural practices or aspects and their pedagogical implications in mathematics education. Rosa and Orey's definition situated mathematics education within social, cultural, and historical contexts which align with the humanistic philosophical orientations of mathematics as discussed in 2.2.2. Thus, ethnomathematics emphasises and appraises the role of everyday contexts in contextualising mathematics. It is in cultural contexts or practices that the current study sought to investigate how pre-service mathematics teacher education prepares student teachers towards incorporating ethnomathematics as a pedagogical approach in mathematics education.

2.6.1 Ethnomathematics program and its dimensions

Ethnomathematics has over the past years gained momentum and developed, as a program which focuses on mathematics situated within cultural aspects (D'Ambrosio, 2001; Hammond, 2000; Orey & Rosa, 2007; Rosa & Orey, 2016). In this regard, Rosa and Orey (2016, pp. 11-13) elaborated six interrelated "dimensions of ethnomathematics program: Cognitive, Conceptual, Educational, Epistemological, Historical, and Political."

2.6.1.1 Cognitive dimension

According to Rosa and Orey (2016), the cognitive dimension focuses on "the acquisition, accumulation, and dissemination of mathematical knowledge across generations" (p. 12). The contention is that mathematics ideas and skills situated in sociocultural contexts from various cultural groups trigger the development of knowledge systems. As result, it might be a difficult task to evaluate cognitive abilities without taking into consideration the impact of sociocultural contexts. Thus, from the cognitive dimension, ethnomathematics views individual cognitive abilities as strongly connected to their sociocultural practices and activities.

2.6.1.2 Conceptual dimension

The conceptual dimension focuses on the development of mathematics knowledge towards resolving challenges associated with everyday life. Thus, various cultural groups consider challenges as opportunities to develop "procedures, practices, methods, and theories" in order to find solutions to such challenges (Rosa & Orey, 2016, p. 12). The contention is that mathematics ideas and knowledge emerge to address the needs and contribute towards decision-making across various cultural groups.

2.6.1.3 Educational dimension

The focus of the education dimension is on the integration of human values and practices in mathematics education (SADBE, 2011; Rosa & Orey, 2016). In this regard, ethnomathematics promotes learners' development of mathematics knowledge by incorporating mathematics practices situated in their everyday contexts. Thus, this dimension emphasise that learners' sociocultural contexts are a gateway towards understanding school mathematics. The implication is that the mathematical ideas and methods developed within learners' sociocultural contexts have pedagogical implications. Consequently, the curriculum should strive towards promoting learners' everyday contexts in their learning processes.

2.6.1.4 Epistemological dimension

The epistemological dimension focuses on "knowledge systems, which are sets of empirical observations developed to understand, comprehend, explain, and deal and cope with reality" (Rosa & Orey, 2016, p. 12). Thus, ethnomathematics argues the development of mathematics knowledge within sociocultural contexts. In this regard, mathematics practices found in everyday contexts such as indigenous games, houses, weaving, murals etc. are considered a starting point towards developing mathematics methods and procedures. This dimension suggests the importance of taking into consideration processes situated in the development of various cultural activities to elicit mathematic ideas in such activities or contexts. In the same vein, François et al. (2015) pointed out that "the epistemological [dimension] is then to determine whether these [cultural] activities relate to mathematical practices, and how" (p. 494). In this regard, emphasis is on understanding the shift from mathematics ideas and methods situated in everyday contexts to abstract mathematics concepts. The epistemological dimension locates the development of mathematics knowledge as a product of people's everyday life. Hence, ethnomathematics offers a new paradigm towards reconceptualisation of power through epistemological reconfiguration, and practical facets of mathematics (Chahine, 2020).

2.6.1.5 Historical dimension

The historical dimension focuses on the connection between the history of mathematics and learners' everyday lives. Rosa and Orey (2016) underscored that the historical dimension provides a basis to examine "the nature of mathematics in terms of the understanding of how mathematical knowledge is allocated in their individual and collective experiences" (p. 13). In other words, mathematics knowledge is developed through comprehension and interpretation of how various cultural groups explained and demonstrated mathematics concepts in their historical contexts. Hence, it is essential to teach mathematics from sociohistorical contexts to develop learners' awareness of contributions from various cultural groups to the development of mathematics knowledge (Chahine, 2011; Gerdes, 2014; Rosa & Orey, 2016).

2.6.1.6 Political dimension

According to Rosa and Orey (2016), the political dimension focuses on the recognition and acknowledgement of the "history, tradition, and mathematical thinking developed by the members of distinct cultural groups" (p. 13). This dimension signifies the importance of all cultural contributions towards the creation of mathematics knowledge. The political dimension highlights the political will in terms of government willingness to develop an education curriculum that resembles mathematical concepts situated within various sociocultural contexts. Within the South African curriculum context, there is an attempt to acknowledge and incorporate learners' sociocultural contexts, however, the CAPS mathematics curriculum does not provide pedagogical guidelines in terms of how mathematics can be contextualised using such contexts. The political dimension may possibly suggest that no cultures should be isolated and undermined in mathematics (D'Ambrosio & Rosa, 2017; Gerdes, 2014).

2.6.2 The importance of ethnomathematics approaches in mathematics education

Ethnomathematics approaches contribute meaningfully to contextualising mathematics. According to D'Ambrosio and Rosa (2017), the integration of ethnomathematics into learning environments may help learners to develop holistic reasoning and acknowledge a variety of philosophical orientations in mathematics. Along the same line, Rosa and Gavarrete (2016) underscored that ethnomathematics aims "to make school mathematics more relevant and meaningful to [learners] in order to increase the overall quality of education and assert more culturally relevant views of mathematics" (p. 26). D'Ambrosio and Rosa (2017) offered two main reasons for the inclusion of ethnomathematics in mathematics classrooms. The first is to "Demystify school mathematics as a final, permanent, absolute, unique form of knowledge" (p. 287). Demystifying school mathematics means changing traditionally dominant misperceptions that mathematics is only for a selected gifted few (D'Ambrosio & Rosa, 2017), a view advanced by the traditional philosophical orientation of mathematics, as discussed above (see section 2.7.1).

The second reason is based on the illustration of the "intellectual achievement of various civilizations, cultures, peoples, professions, and genders" (D'Ambrosio & Rosa, 2017, p. 287). They argued that Western mathematics is linked with colonial powers which sought to dominate epistemological orientations. Such early perceptions "on the history of mathematics are fraught with chronological and epistemological trajectories depicting mathematics as a creation of

Western civilisations that conquered and dominated the entire world" (Chahine, 2020, p. 97). Furthermore, D'Ambrosio and Rosa (2017) cautioned that "The acceptance, forced or voluntary, of western mathematics and western knowledge in general leads to the acceptance of behavior and values, of ideas like the winner is the best, the losers are to be discarded" (p. 287). The view is that there is a rich historical account of mathematics situated within diverse cultural contexts. Hence, numerous researchers commonly agree that mathematics concepts and ideas exist in cultural practices (Machaba & Dhlamini, 2021; Moloi et al., 2021; Sharma & Orey, 2017; Spangenberg, 2020). Therefore, ethnomathematics can promote learners' abilities to link school mathematics and their everyday sociocultural contexts.

2.6.3 Contextualising mathematics content

Mazzeo (2008, cited in Van der Walt et al., 2019, pp.191-192) considered contextualisation as pedagogical approaches intended "to make the learning of (Mathematics) skills, content and language accessible by focussing teaching and learning on concrete applications in a specific (familiar) context." As mentioned earlier, the CAPS policy document recognises and affirms the contextualisation of mathematics as the focal point of the mathematics curriculum. According to SADBE (2011), contextualisation refers to inclusion of but not limited to cultural practices or aspects in contextualising mathematics. Thus, learning mathematics concepts that are situated in learners' real-life contexts, such as culture or cultural practices, provides possibilities for ethnomathematics pedagogies in the classroom (Chahine, 2016; Chahine et al., 2013; Jagals & Van der Walt, 2016; Van der Walt et al., 2019). In the same vein, Sharma and Orey (2017) argued that contextualisation "is the most powerful and influential factor because it focuses on and relates to learners' prior knowledge to the mathematics of the classroom" (p. 156).

De Beer and Van Wyk (2019) maintained that "learners do not enter the STEM classroom as tabula rasa, and they almost always have localised IKS [in this case ethnomathematics] that could contextualise the often abstract [Mathematics] curriculum content better" (p. 118). Van der Walt et al., (2019) posited that contextualising Mathematics concepts through ethnomathematics contexts such as games and music may promote learners' active participation in the learning process. The contention is that contextualising mathematics through ethnomathematics epistemologies could serve as an essential point towards understanding mathematics concepts. Thus, ethnomathematics, when infused in the mathematics curriculum, will facilitate epistemological access for learners to make sense of and develop their worldviews in mathematics. By contextualising mathematics through ethnomathematics, worthwhile learning results in the mathematics classroom may be realised.

Furthermore, contextualising mathematics through ethnomathematics further offers learners opportunities to experience mathematics in their everyday life and improve the conceptual understanding of mathematics concepts within the problem-solving context (Moloi, 2015; Moloi et al., 2021; Rosa & Shirley, 2016; Sharma & Orey, 2017; Spangenberg, 2020). According to Rosa and Orey (2016), ethnomathematics can raise learners' awareness that mathematics is part of their everyday life. In Madusise's (2015) view, learners' cultural contexts are important because they are part of their life experiences, and they offer significant references to concrete mathematics contexts. The assertion is that ethnomathematics provides learners with opportunities to relate mathematics embedded in cultural practices to school mathematics. When learners experience mathematics in context (like indigenous games or traditional buildings), it suddenly becomes meaningful and their attitude changes and they become interested in mathematics (Van der Walt et al., 2019). Moreover, Sharma (2012) illustrated the dire consequences of exposing learners to only the Western perspective, stating that when learners learn to see mathematics only from a foreign [Western] perspective, they may believe that [their] culture is less powerful and might not work with mathematics.

2.6.4 Mathematising mathematics

According to Rosa and Orey (2013), mathematisation is defined as "a process in which individuals from different cultural groups come up with different mathematical tools that help them organize, analyze, comprehend, understand, and solve specific problems located in the context of their real-life situation" (p. 118). Similarly, Freudenthal (1991) considered mathematisation as an identification and analysis of mathematics concepts and procedures situated within everyday contexts which can be applied in problem solving. These definitions of mathematisation reveal the importance of learners' cultural context towards solving mathematics problems. In this instance, mathematics problems are situated within learners' sociocultural contexts. The definitions further suggest that for contexts from learners' cultural practices or everyday life to be relevant and meaningful in mathematics, they have to be mathematised. Hence, Madusise (2013) considered cultural practices or activities as essential contexts to explore mathematics ideas.

Van den Heuvel-Panhuizen (2010) and Van den Heuvel-Panhuizen and Drijvers (2010) identified two important types of mathematisation: horizontal mathematisation and vertical mathematisation. On the one hand, horizontal mathematisation is characterised by the transition from learners' everyday contexts to abstract mathematics. In particular, Knott (2014) pointed out that mathematics found in everyday contexts can enhance learners' abstract thinking. In this instance, learners may use mathematics strategies found in their cultural or everyday contexts to understand abstract mathematics concepts learned at school. Mathematisation appears to acknowledge the role of learners' sociocultural contexts in developing learners' mathematical thinking and understanding. The contention is that teaching mathematics in abstraction without considering learners' prior knowledge embedded in their cultural practices may not develop learners' understanding in mathematics. On the other hand, vertical mathematisation is defined as "the process of reorganisation within the mathematical system resulting in shortcuts by making use of connections between concepts and strategies" (Van den Heuvel-Panhuizen, 2010, p. 4).

The current study investigated how pre-service mathematics teacher education prepares student teachers in ethnomathematics, which provides rich contexts for mathematisation. This intention was driven by the assertion that pre-service education is inadequately equipping student teachers to effectively work with culturally diverse student populations (Namatovu, 2015). Namatovu further highlighted that mathematics teachers struggle to implement teaching strategies that cater for diversity.

2.6.5 Culturally responsive pedagogy and ethnomathematics

According to Ladson-Billings (1995a), culturally responsive pedagogy (CRP hereafter) refers to "a theoretical model that not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate" (p. 469). CRP is based on the premise of advancing both social and cultural fairness in pedagogies. Furthermore, CRP shares the same attributes as ethnomathematics in that it promotes learners' sociocultural contexts and "prior experiences as frames of reference… [to make western mathematics] more relevant and effective for them" (Gay, 2010, p. 29). Western mathematics, as utilised throughout the world, is provided in the abstract form and therefore learners perceive that they will never use mathematics in their own lives. The negative implications of excluding learners' cultural contexts is further evident in Fouze and Amit's (2018) arguments that teaching mathematics "in a completely abstract, symbolic, and meaningless manner that is remote from cultural aspects is not merely ineffective; it is actually harmful to the students, society, math itself, and future generations" (p. 620).

Furthermore, Taylor and Sobel (2011) underscored that CRP is characterised by teachers' abilities to integrate learners' cultures as part of pedagogical resources. In the same vein, Sharma and Orey (2017) illustrated that CRP can assist "teachers to make mathematics learning contextual and create activities where students can easily relate to their own culture and everyday life" (p. 161). Thus, CRP, like ethnomathematical perspectives, provides evidence that learners' prior knowledge, based on their cultural practices and activities, could be beneficial in their learning processes. Hence, Harding-DeKam (2014) noted that the importance of "teaching mathematics through culture is an awareness that integrates prior knowledge of [learners] in a way that builds upon what they already know leading to mathematical understanding" (p. 3).

Ethnomathematical perspectives and CRP concepts perceive learners' cultural knowledge as the foundation for learning mathematics (Rosa & Orey, 2016). In this regard, ethnomathematical perspectives and CRP seek to examine cultural influences on the process of learning and teaching mathematics. Hence, Sharma and Orey (2017) and Balamurugan (2015) agreed that the use of learners' cultural practices make academic mathematics accessible to learners.

Furthermore, Rosa and Orey (2011) argued that ethnomathematical perspectives share a vision with CRP since they encourage teachers to promote learners' sociocultural or everyday contexts to develop their cognitive skills in mathematics. Hence, it promotes cultural contexts in mathematics (Sharma & Orey, 2017). From Rosa and Orey's (2008) point of view, these cultural experiences and practices act as bridges for providing learners with insights into mathematical knowledge. The argument provided for integration of ethnomathematical perspectives in classrooms is to demonstrate that learners' cultural contexts do contribute to mathematical thinking (Shirley & Palhares, 2016). Shedding more light on both ethnomathematical perspectives and CRP, Hart (2003, p. 42) asserted, "the views of pedagogy within the literature on ethnomathematics are compatible with work on culturally relevant pedagogy." These essential aspects of ethnomathematics and CRP can make a difference in the teaching and learning of mathematics. As a result, it is important that mathematics teachers possess knowledge and skills to build from their learners' prior knowledge shaped by cultural contexts. Hence, in this study I focused on how pre-service mathematics teacher education equips student teachers with ethnomathematics to contextualise mathematics.

2.6.5.1 Main tenets of Culturally Responsive Pedagogy

Ladson-Billings (1995b) discussed three main tenets of CRP: academic achievement for all students, cultural competence and critical consciousness.

2.6.5.1.1 Academic achievement for all students

Firstly, academic achievement for all learners is promoted through this pedagogy as learners that are exposed to CPR experience significant achievement in mathematics (Leonard et al., 2010; Moran, 2020; Rosa & Orey, 2010). CRP also has the potential to develop and nourish learners' mathematical identities, which are essential for their achievement in mathematics (Leonard et al., 2010). Hence, other researchers have agreed that teaching mathematics in a way that is divorced from learners' cultural experiences appears to affect their achievement negatively (Gerdes, 2009;

Lopes & Cox, 2018). Thus, this pedagogy acknowledges and embraces learners' cultural knowledge as a basis to promote their academic achievement in mathematics. Adam (2004) argued that "classrooms or learning environments cannot be isolated from the communities in which they are embedded" (p. 49). These perceptions propose that learners should be taught mathematics using prior knowledge premised on their sociocultural contexts. Hence, teachers should be able to integrate learners' sociocultural practices as a frame of reference and connect it to mathematical knowledge (Fouze & Amit, 2018; Namatovu, 2015; Sharma & Orey, 2017; Van der Walt et al., 2019).

2.6.5.1.2 Cultural competence

Cultural competence relates to learners "being able to maintain who they are while negotiating the academic demands and coping with the dominant mainstream culture present in their schools" (Hubert, 2013, pp. 56-57). In the same vein, Sharma and Orey (2017) also agreed that CRP helps learners to succeed without losing their cultural identities in the learning processes. These authors suggest that there is a need to create a learning environment that acknowledges and embraces diverse learners' cultures. Various cultural aspects such as language, practices, music, art, clothes, and weaving should be utilised as teaching resources so that learners are able to succeed.

2.6.5.1.3 Critical consciousness

CRP develops learners' critical consciousness. This aspect develops learners' cognitive abilities to "realize that social inequities exist within our society … analyze and critique these social inequities using the content being taught in the classroom" (Hubert, 2013, p. 57). Hubert further argued that such cognitive abilities are considered essential towards developing learners as "productive citizens in a democratic society" (p. 57). Hence, Ladson-Billings (1995b) contended that "it is enough for students to choose academic excellence and remain culturally grounded if those skills and abilities represent only an individual achievement" (p. 162). These CRP assertions are evident in South African student protests (see section 2.6.9) which challenge colonial education structures in a democratic country. Thus, CRP does not only equip learners academically but also empowers them to contribute constructively to social discourses. The contention appears to be that CPR enables learners to apply the knowledge meaningfully to their everyday lives.

2.6.6 Studies that focused on ethnomathematical perspectives

Literature reveals three standpoints on the incorporation of IKS in the science curriculum (Taylor & Cameron, 2016; Zinyeka et al., 2016). These perspectives are: (i) the inclusive perspective, which focuses on IKS as part of science. In the context of this study, the inclusive perspective focuses on ethnomathematics as part of the western mathematics curriculum; (ii) the exclusive perspective, focusing on "IKS [ethnomathematics, in this case] and science [mathematics, in this case] as separated bodies of knowledge" (Taylor & Cameron, 2016, p. 3). In this regard, the exclusive perspective advances that ethnomathematics should not be part of the mathematics curriculum, due to the different tenets; and (iii) IKS and science as intersecting domains. This perspective advocates epistemological border-crossing where elements of ethnomathematics could be incorporated in the mathematics curriculum. Based on the latter perspective, I investigated the affordances of ethnomathematical perspectives in pre-service mathematics teacher education.

2.6.6.1 Ethnomathematics and learners' performance in mathematics

The literature reviewed has shown that ethnomathematics could enhance learners' performance in mathematics. For example, studies conducted by Unodiaku (2013) and Achor et al., (2009) focused on the effectiveness of ethnomathematics perspectives in enhancing learners' achievement in mathematics. In these studies, quasi-experimental research designs were adopted. Senior secondary learners (equivalent to Grades 10-12 in South Africa) from different regions in Nigeria participated in the studies. In the latter study, an ethnomathematics achievement test was used as a data collection instrument while the former study relied on a geometry achievement test. The experimental groups were taught through ethnomathematical perspectives and control groups through conventional teaching approaches. The analysis of the results revealed that learners exposed to ethnomathematical perspectives achieved better than their counterparts taught with the conventional approach.

Although emphasis in the afore-mentioned research was on secondary school contexts, Abiam et al., (2016) conducted a study that involved primary school learners. In their study, they investigated the effects of ethnomathematics on learners' performance in geometry. The findings of their research revealed that learners exposed to ethnomathematical perspectives outperformed their counterparts taught using the conventional method. These studies (Abiam et al., 2016; Achor et al., 2009; Unodiaku, 2013), regardless of different schooling contexts, show the importance of incorporating ethnomathematical perspectives as a pedagogical approach in mathematics learning environments. These studies provide evidence that when teachers use ethnomathematical perspectives as part of their pedagogical approaches, learners' understanding, and performance can be improved.

2.6.6.2 Teachers' perceptions and preparedness on Ethnomathematics

Previous studies conducted by Mania and Alam (2021), Orim and Uzoma (2019), and Thakur (2019) focused on teachers' perceptions regarding ethnomathematics as a pedagogy. Empirically, Orim and Uzoma (2019) argued that there is a correlation between teachers' perception and awareness regarding the use of ethnomathematics in mathematics classrooms. Similarly, Mania and Alam (2021) found that teachers who perceive the ethnomathematics approach positively can use cultural practices such as games to teach mathematics. What can be understood from these studies is that when student teachers are trained in ethnomathematics approaches, they are likely to develop positive perceptions and use ethnomathematics in their classrooms. Conversely, student teachers who are not exposed or trained in ethnomathematics approaches are unlikely to use such approaches in their mathematics classrooms.

Furthermore, Sunzuma (2019) investigated Zimbabwe's "mathematics teachers' preparedness to integrate ethnomathematics approaches into the teaching and learning of geometry" (p. viii). A pragmatist research paradigm and convergent parallel mixed methods were adopted. The participants in the study were 40 mathematics teachers studying in the Bachelor of Science Education Honours programme. A questionnaire and focus group discussions were used to collect data. The results of the study pointed out teachers' lack of knowledge on how to incorporate ethnomathematics. What can be understood from Sunzuma's (2019) findings is that pre-service mathematics teacher education did not prepare teachers with regard to ethnomathematics approaches. Hence, in the current study, I explored the affordances of ethnomathematics in pre-service mathematics teacher education.

Chahine's (2013) study examined mathematics teachers' investigations of mathematics knowledge situated within various cultures in African contexts. The participants in the study were 14 mathematics teachers who enrolled in the Indigenous Mathematical Knowledge Systems (IMKS) module. The focus of the module was to provide teachers with opportunities to "experience the realities of knowing and doing mathematics amidst contextual challenges" (Chahine, 2013, p. 3). Chahine's (2013) study further showed the importance of sensitising teachers to different indigenous contexts which is essential towards developing their acknowledgement of different thinking informed by various cultures. The findings of the study indicate that students demonstrated growth in the significance of exploring multiple approaches to knowledge.

Spangenberg (2020) explored South Africa's student-teachers' views on the affordance of integrating cultural tools in mathematics lessons in South Africa. 11 in-service teachers from diverse cultural groups studying towards a Bachelor of Education honours degree in mathematics education at a university in Johannesburg participated in the study. Although Spangenberg used the term student-teachers, it should be understood as in-service teachers as they were employed full-time as mathematics teachers. The participants were involved in classroom action research (CAR), which involved processes such as identifying, planning, acting, and collecting data, and evaluating cultural artefacts. These involved participants presenting mathematics lessons and observing and interviewing learners during mathematics activities. Subsequently, participants wrote the short reports which were used as the main sources of data in Spangenberg's (2020) study. It was found that the integration of cultural artefacts in mathematics lessons, among others, allow for the teaching of specific mathematics concepts. What can be understood from Spangenberg's (2020) findings is that when student teachers are trained in ethnomathematics, they may develop in-depth pedagogical knowledge to apply it in their own classrooms.

2.6.6.3 Pedagogies of play and traditional games

Fleer and Veresov (2018) defined pedagogies of play (PoP hereafter) as pedagogical models that support the development of play from the perspective of learners. PoP provide learners with new learning experiences that facilitate the construction of new knowledge (Van der Walt et al., 2019). Thus, it appears that PoP may develop and improve learners' mathematical knowledge and skills. PoP is characterised by a learning environment which allows learners to take risks, explore new ideas, accept challenges, and make and learn from their mistakes (Mardell et al., 2016; Remer & Tzuriel, 2015). According to Van der Walt et al., (2019), using IKS embedded in games and music are some ways through which PoP could be utilised in the teaching and learning of mathematics.

In the past years, the incorporation of indigenous games from various cultures has attracted much attention in mathematics education (Cahyaningati & Diana, 2022; Fouze & Amit, 2018; Moloi, 2013, 2014; Moloi et al., 2021; Mosimege, 2020; Nabie, 2015; Nkopodi & Mosimege, 2009; Owusu-Mensah & Baffour, 2015; Van der Walt et al., 2019; Dewah & Van Wyk, 2014). These authors commonly agree that indigenous games provide opportunities to contextualise mathematics concepts such as quadrilaterals, symmetry, ratio, fractions, and proportion and can be taught through traditional games. Van der Walt et al., (2019) have maintained that the use of traditional games such as Morabaraba provide learners with opportunities to relate their experiences outside the classroom to mathematical concepts and processes encountered in their mathematics classroom. In the same vein, Cahyaningati and Diana (2022) asserted that integrations of indigenous games can play an essential role in preserving local culture(s).

Consequently, it is essential for teachers to develop pedagogical knowledge to utilise traditional games in their classrooms. Hence, Van der Walt et al., (2019, 2021) focused on teachers' professional development of integrating traditional games such as Morabaraba (see Figure 2-1 below) and Ncuva towards contextualising mathematics concepts.

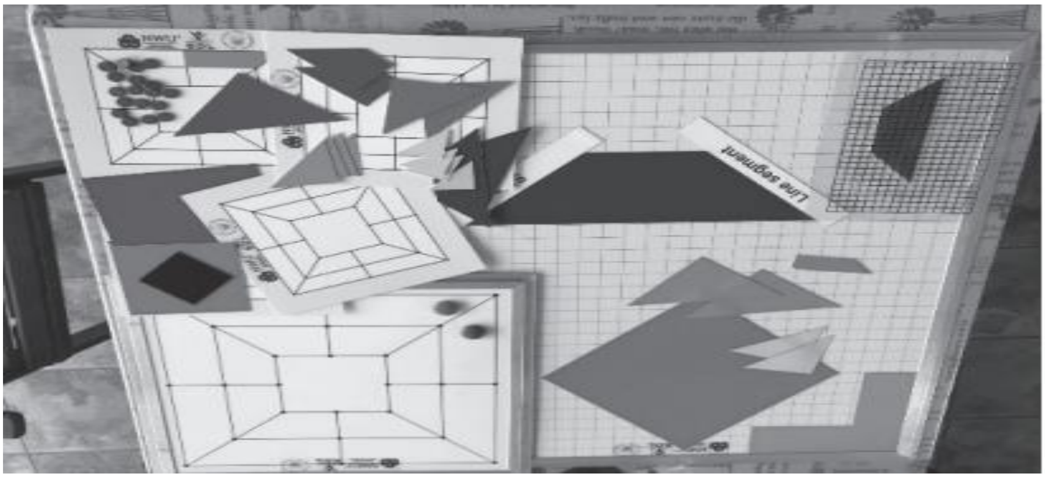


Figure 2-1: Morabaraba board game and puzzles-TSMK.

(Source: Van der Walt et al., 2019, p. 201)

While Van der Walt et al., (2019, 2021) focused on teachers' professional development, researchers such as Moloi (2014) used Morabaraba to teach Grade 10 learners mathematics concepts. Through engaging in mathematical activities based on Morabaraba, learners were not only able to identify mathematics concepts but were able to perform high cognitive and synthesis skills (Moloi, 2014). The contention is that traditional games could help teachers to teach mathematics in meaningful and stimulating ways, which will result in learners' active involvement in their learning processes.

In addition, when Morabaraba is used in the mathematics classroom, it is important to develop a plan of action (see Table 2-4) as suggested by Moloi (2014). The implication of the action plan is to help teachers with how they can develop their lesson plans. The plan of action in Table 2-4 entails various activities and evaluation tools, which offer guidelines in contextualising mathematics though learners' real-life contexts. In addition, the plan helps learners to concretise the mathematical content and skills (Moloi, 2014). This happens when learners are afforded opportunities to reflect on the lessons learnt from playing the game. Thus, reflections are a starting point towards discussion and examination of mathematical ideas embedded in the game. Furthermore, assessment in the form of activities should be central to the use of traditional games in the classroom. These activities should be based on the games so that learners will be able to relate mathematical concepts found in the games to their classroom learning.

Table 2-4: Plan of action.

Activities	Person responsible	Monitoring	Evaluation	Timeframe
Phase 1: Playing of Morabaraba game	Two pairs of learners and parents volunteered to play the game	Mathematics teachers and other research participants	Observation sheet used to record observations	45 minutes
Phase 2: Reflection on the lesson learnt	Grade 10 class and the focus group	Mathematics teachers and other research participants	Discussion on mathematics concepts/skills/knowledge identified from the game	30 minutes
Phase 3: Presentation of the lesson	Subject teachers; The researcher or the Grade 10 teachers or mathematics subject advisors	Mathematics teachers and other research participants	Lesson plan is crafted based on the identified mathematical concept	60 minutes
Phase 4: Reflections on the lesson presented	Grade 10 class and the focus group	Mathematics teachers and other research participants	Comments and recommendations from other research participants	30 minutes
Phase 5: Assessment of the lesson	Teacher assessment, peer-assessment, and parent assessment	The presenter and other subject experts	Give feedback on activities done during class, after class or at home	45 minutes

(Adapted from Moloi, 2014, p. 587).

In other studies, Moloi et al. (2021) explored the importance of *Kgati* (skipping rope) in the teaching and learning of word problems in Grade 4 mathematics. The results of the study reveal that learners can interpret, convert, and link their indigenous knowledge with mathematics and improve their understanding of mathematics concepts such as geometry shapes and fractions. They further indicate that the incorporation of *Kgati* moves not only improved learners' mathematics knowledge but significantly improved learners' creativity and imagination. The contention is that traditional games should be viewed beyond the generally perceived notions of play and enjoyment, but as learning tools that can help learners learn mathematics in practical and meaningful ways.

2.6.6.4 Traditional buildings

From research on ethnomathematics, different researchers who focused on the role of traditional buildings in mathematics education can be distinguished. Table 2-5 provides a tabular representation of researchers and their findings on traditional buildings from ethnomathematical perspectives:

Table 2-5: Research on the role of traditional buildings in mathematics education

Researcher(s)	Year(s)	Place/Country	Methods and findings
Ditasona	2018	Toba Samosir, Indonesia	Ditasona's study conducted observations and interviews with the Gorga craftsmen (pande) to explore mathematical concepts that are used in making Gorga motifs. The findings showed that some gorga motifs use the principle of reflection, rotation, translation, and dilatation in making Gorga. The study further noted the accuracy of their calculations by using simple tools of their day requires a mathematical ability that is good enough for the craftsman in making a motif gorga. The study provides evidence that mathematical concepts such as transformation are used in construction of the gorga motifs.
Trinick et al.	2017	Hamburg, Germany	The study explored mathematics symbols embedded within *Wharenui* (Māori traditional houses) in Germany. The rationale was to demonstrate the relationship between symmetry concepts and culture from ethnomathematical perspectives. They argued that "there is a need to better understand how the cultural significance can be connected to mathematical understandings in a way that gives value to both" (p. 235). The analysis of various traditional houses revealed evidence of symmetry concepts. It was found that concepts such as enlargement rotation, and reflection are embedded in various patterns in Wharenui meeting houses.
Suharta et al.	2017	Indonesia	The aim of their study was to investigate mathematics concepts involved in Balinese traditional houses through the ethnomathematics lens. Data collection methods included interviews, observations, and questionnaires. In this exploratory study, "3 carvers and 2 builders of Balinese traditional houses" served as participants (p. 47). Observations were carried out to gain insight into the mathematics concepts found in Balinese Traditional Carvings and Buildings. The profile of the participants was collected by using questionnaires. Furthermore, data triangulation was strengthened by using interviews. The findings of this study revealed that reflection and similar are evident in Balinese Traditional House Carvings.

Seroto	2012	Limpopo Province, South Africa	The purpose of this research was to investigate "the mathematical concepts of the buildings of the Limpopo Province…and the teaching of high school mathematics" (p. vi). The participants in the study were traditional house builders and Grade 12 mathematics teachers from various districts in Limpopo Province. Seroto conducted interviews with traditional house builders. Data involving mathematics teachers were collected by means of a questionnaire. The findings of the study revealed that traditional house builders were not able to explain, using mathematical language, the construction of the houses. The findings further highlight that geometry concepts embedded in traditional houses can be used in the teaching and learning of mathematics.
Soares	2009	Zambézia and Sofala Provinces, Mozambique	The aim of this study was to explore the "incorporation of the geometry involved in the traditional house building in Mathematics Education in Mozambique" (p. vi). Soares conducted interviews with traditional house builders from various regions in Zimbabwe. Furthermore, data were also collected by using observations. Literature review on African traditional houses was conducted. Soares's study provided evidence that traditional houses can be used as sociocultural contexts to teach geometry concepts such as angle, circle, rectangle.

Table 2-5 shows numerous studies that primarily focused on mathematical concepts embedded in traditional buildings. For example, Seroto (2006) conducted an ethnographic study that explored geometry in traditional houses (see Figure 2-2) and their relationship to classroom learning. The study revealed geometry concepts (e.g., reflection and circle) are immersed in the construction of the rondavels. Similarly, Soares (2009) found that terms such as angle, circle, and rectangle for elementary geometry exist in the traditional houses. These studies provide evidence that the builders of various traditional houses use geometric concepts during the design and construction processes. Hence, researchers such as Bhuda (2019) found that Ndebele traditional buildings found in Mpumalanga Province provide evidence of ethnomathematical knowledge. Unlike other studies, Seroto's (2006) focused on not only the builders but learners as well. In Seroto's (2006) study, Grade 11 learners were given an investigation task involving observation of mathematics concepts in traditional rondavel buildings. The involvement of learners develops their abilities to discover mathematical concepts used in the traditional buildings. Likewise, Muhammad et al.' (2020) study found that elementary learners (Grades 1, 2 & 3) were able to identify square, rectangle, triangle, and circle from the Borobudur temple.

Figure 2-2: Traditional circular building.

(Source: Seroto, 2006, p. 43).

Traditional building builders are often aware of mathematical concepts involved in the construction of these buildings. Suharta et al. (2017) found that Balinese traditional houses' (see

Figure 2-3) carvings and builders use the concepts of similarity, shift and reflection in their work. This is very similar to what Ditasona (2018) found the principles of reflection, rotation, translation, and dilatation are used in making Gorga. Thus, Ditasona (2018) have focused on the mathematical thinking processes Gorga craftsmen used to construct Gorga. However, Ditasona's study revealed that not all traditional builders are aware of mathematical concepts involved in the building of these houses. Similarly, Seroto (2012) also found in his study that the traditional house builders "could not explain using the mathematical language, how they constructed the buildings" (p. vii).

Figure 2-3: Balinese traditional house.

(Source: Suharta et al. 2017, p. 2).

Seroto (2012) went further to focus on mathematical concepts embedded in traditional houses and how they can be used as a point of reference in the teaching of high school mathematics. What set this study apart from the previous study (see Seroto, 2006), is his emphasis on the challenges that high school mathematics teachers experience in contextualising mathematics concepts using traditional buildings. Unlike Seroto's (2006) study, his 2012 study limited itself to Grade 12 teachers and circular house builders. The suggestion from Seroto's (2012) study highlights that "teacher training courses and programmes should include also courses on culture, society, the relationship between mathematics and culture, and the history of evolution of mathematical concepts" (p. vii). The suggestions provide evidence that teachers should be trained in ethnomathematics approaches. It is in such suggestions that this multiple case study finds relevance in exploring how pre-service mathematics teacher education prepares student teachers for ethnomathematics.

2.6.6.5 Traditional dance, music, and mathematics

A considerable amount of literature has been documented on the pedagogical implications of traditional dance and music in mathematics (Buranich, 2016; Helsa & Hartono, 2011; Kalpana, 2015; Mbusi, 2011; Tokhmechian & Gharehbaglou, 2018; Van der Walt et al., 2019). Music and dance are integral parts of human social activity (Van der Walt et al., 2019), and can address multiple intelligence (Gardner, 2008). Along the same line, Potgieter (2020) argued that “Musical intelligence can be incorporated by allowing learners to write rap songs about the mathematics content, or to perform a dance to illustrate certain principles, which accounts for a lot of creativity and fun in the mathematics classroom” (p. 34). Furthermore, research has shown that musical intelligence has a positive impact on the enhancement of learners' ability to establish mathematical connections (Kusuma & Dwipriyoko, 2021; Rifqi et al., 2021). The argument is that music and mathematics share an important connection which can bring out effective teaching and learning of mathematics where learners are interested to learn. Hence, there is a contention that traditional dance can be a useful tool in teaching mathematics concepts such as geometry (Kalpana, 2015), number patterns and fractions (Mbusi, 2011).

In one such study that focused on music, Van der Walt et al. (2019) integrated music and boomwhackers to contextualise the common fraction concept. They defined boomwhackers (see Figure 2-4) as “coloured plastic tubes, accurately cut into specific lengths to produce different tones when hit against a surface (table, hand or floor)” (p. 201). Music symbols of songs were transposed to fractions. Their findings provide evidence that the use of music and boomwhackers offers teachers opportunities to create new learning environments for their learners. In the same vein, Redman (2016) argued that “when using the body through dance and movement to explore academic [mathematics] concepts, learners are given an opportunity and creative outlet to deepen their understanding of the content” (p. 30). In other words, traditional dance offers learners opportunities to experience a physical sensation of abstract mathematical concepts.

Figure 2-4: Boomwhackers.

(Source: Van der Walt et al., 2019, p. 201).

Traditional dance and music not only help learners to understand mathematics concepts, but enhance their cognitive development (Evangelopoulou, 2014; Kusuma & Dwipriyoko, 2021). Through dance and music, learners may improve their cognitive abilities in mathematics. Along the same line, Becker (2013) and Soares and Lucena (2013) underscored that dance promotes learners' autonomy, high thought process and confidence in undertaking initiatives in their learning activities.

2.6.6.6 Weaving and mathematics

Further studies explored mathematical concepts and skills that are found in weaving. For example, mathematical concepts such as counting, vertical and horizontal symmetry, and reflection, and translation were evident in the weaving activity (Aboagye, 2015; Cherinda, 2012; Dominikus et al., 2017; Gerdes, 2011; Hidayat, 2021; Mosimege, 2017; Pradhan, 2020; Thompson, 2020). In addition, geometry shapes can also be found in various weaving designs. The assertion is that the weaving activity can be used to contextualise mathematics concepts. Furthermore, using woven fabrics as a learning resource makes learning more contextual and helps learners build awareness of the fact that mathematics is manifested in cultural artefacts and practices such as weaving (Dominikus et al., 2017).

The above-mentioned studies on various cultural practices are evidence that culture can be integrated to contextualise mathematics teaching. They also provide rich evidence of cultural contexts that have mathematical concepts. Such contexts can facilitate learners' transition into the abstract world of academic mathematics.

2.6.6.7 Ethnomathematics and indigenous languages

Language is considered as a main feature of any culture (Mosimege, 2017) and serves as an essential communication tool (Alexander, 2005). The contention is that cultural contexts cannot be isolated from the language in which they were developed (Meaney et al., 2008). In other words, using a different language to explore mathematics found in various cultural practices may "have an impact on how the practices are perceived by students" (Meaney et al., 2008, p. 52). The suggestion is that indigenous languages play an essential role towards understanding ethnomathematics practices. Thus, cultural practices in ethnomathematics contexts should be explored and interpreted within language linked with such practices.

Although South Africa has 11 official languages, its education systems still support English and Afrikaans rather than African languages when operating in official domains (Bhuda & Pudi, 2020). Thus, the curriculum "endorses that in some schools' English ought to be the language of instruction, while in other schools Afrikaans is considered the language of instruction" (Bhuda & Pudi, 2020, p. 34). Alexander (2005) further argued the importance of language, stating that "the specific language(s) in which the production processes take place become(s) the language(s) of power. To put it differently, if one does not command the language(s) of production, one is automatically excluded and disempowered" (p. 2). My understanding of Alexandar's argument is that when learners or students are not learning mathematics in their own languages, they may become excluded and disadvantaged. In other words, learners may struggle to understand mathematics, not necessarily because they find mathematics difficult but because of the language in which it is presented. Hence, mathematics learning difficulties may become "increased when the language in which it is being taught is not the students' first language" (Meaney et al., 2012, p. 1). This fact was clearly illustrated by Bhuda and Pudi (2020) who pointed out that "learners with an African home language have essentially continued to perform at worse [in mathematics] than those who have English as their home languages" (p. 34). The contention is that indigenous languages do not only have an impact on learners' understanding of mathematics (Stathopoulou & Kalabasis, 2006), but learners become comfortable in using it to elaborate on mathematics concepts (Mosimege, 2017).

On the other hand, a recent study conducted by Mpalami (2022) found that "during the translation process, the educator went as far as translating mathematics technical terms" (p. 1). He further elucidated that "such translation distorted the meaning of the original task and therefore made it hard for learners to comprehend concepts as envisioned" (Mpalami, 2022, p.1). In another study, Bell (1993), contended that the use of learners' indigenous languages may not necessarily enhance the achievement in mathematics because of highly specialized mathematical terms with a divergence of meaning from those used in every day language. Bell's (1993) assertion does not necessarily disregard the use of indigenous languages in mathematics but seeks to demonstrate that learners "have to first struggle with the English language and thereafter with the mathematical language" (Anyagh et al., 2016, p. 95). This implies that learners will struggle with both English and mathematics at the same time. However, when learners learn mathematics in their indigenous languages, they do not have to battle difficulties in English as mathematics concepts are presented in the language they comprehend better. Along the same line, Mpalami (2022) argued the importance of translating mathematics activities into learners' home languages in order to assist African learners in South Africa whose mother tongue is not English or Afrikaans to gain a better understanding of mathematics. These studies infer that learners' difficulty in understanding the English language may further deepen their difficulties in mathematics.

2.6.7 Ethnomathematics studies in pre-service teacher education

Al-Mahdi (2020) conducted action research on the student teachers' explorations of ethnomathematics in their social context. In the study, he did not only seek to develop student teachers' knowledge regarding the connection "between mathematics, history, society, and culture in Bahrain" (Al-Mahdi, 2020, p. 26), but also enhance his own pedagogical approaches by integrating ethnomathematics as a teaching strategy. The intention was to explore methods for integration of ethnomathematics as an alternative teaching approach towards curriculum design. Data were collected through personal observations and classroom activities. Analysis of the data revealed that student teachers became aware of mathematics embedded in various sociocultural contexts. Furthermore, it was found that the student teachers "developed a sense of ownership of their learning because they were encouraged to discuss the project's activities, negotiate their suggestions and give feedback during each step" (p. 26).

Albanese and Perales (2020) investigated mathematical conceptions of student-teachers from ethnomathematical perspectives. In their study, they developed and presented an ethnomathematics workshop which sought to promote student-teachers' reflection on the nature of mathematical knowledge. The participants in the study were 14 student-teachers enrolled in the optional course on "Workshop of Mathematical Modeling and Production" in the mathematics teachers' degree at the University of Buenos Aires. Some of the activities involved a description of the braid-making process and development of a shared creative representation. Data were collected through audio-visual recordings, transcripts, field notes, evaluation sheets of the two course teachers, worksheets of all participants, and an open questionnaire. The analysis of the data revealed that the workshop proved to be a fruitful environment for student teachers to become aware of and make observations that demonstrate their understanding of what is mathematics.

The present study involved an ethnomathematics workshop, as with Albanese and Perales's (2020) study; however, their study was limited to student teachers reflecting on the nature of mathematical knowledge. In this current study, the focus, amongst others, was exploring student teachers' perceptions with regard to ethnomathematics and how they are prepared to use it as a contextualisation pedagogy to contextualise mathematics topics. Thus, the role of the workshop in the current study was to equip student teachers with pedagogical knowledge and skills to use learners' sociocultural contexts in their prospective classrooms.

2.6.8 Challenges of incorporating ethnomathematical perspectives in the classrooms

There are numerous challenges related to the incorporation of ethnomathematics perspectives in mathematics classrooms. For instance, research undertaken by Seroto (2012) pointed out that teachers lack pedagogical knowledge for integrating cultural artefacts in mathematics. In the same vein, Aikpitanyi and Eraikhuemen (2015) also found that mathematics teachers have a low awareness of ethnomathematical perspectives. From Orey and Rosa's (2007) point of view, teachers under preparedness limits the possibility of integrating the ethnomathematical perspectives into the mathematics classrooms. Namatovu (2015) attributed teachers' lack of knowledge to pre-service teacher education programmes that do not prepare them to teach culturally diverse learners. Jagals and Van der Walt (2016) underscored this by saying that teachers who have been raised, taught, and qualified through a Westernised scientific view do not necessarily have the relevant background, knowledge and understanding of exactly what ethnomathematical perspectives to include in the curriculum, or how to do so. In addition, a paucity of ethnomathematics in the pre-service mathematics education course leaves teachers and researchers unprepared to argue this issue and leaves the door open to further critics of the field (Orey & Rosa, 2007).

To respond to the above-mentioned challenges, in-service teacher education should offer courses, workshops, or seminars to popularise and sensitise mathematics teachers on the use of ethnomathematical perspectives (Abiam et. al., 2016; Balamurugan, 2015; Aikpitanyi & Eraikhuemen, 2015; Unodiaku, 2013). Thus, a reason in-service teacher education is recommended could possibly be that pre-service mathematics education might not be exposing prospective teachers to ethnomathematics. In my view, although these studies emphasise in-service education, it is equally important for pre-service mathematics teacher education to be at the forefront of equipping student teachers with ethnomathematics perspectives. Hence, Katsap and Silverman (2008) argued that there is no reason for a teacher education curriculum to ignore ethnomathematics approaches. Thus, student teachers should be equipped with ethnomathematical perspectives during their pre-service mathematics education training since they cannot teach beyond the scope of their pedagogical knowledge (Van Putten et al., 2010).

In addition, Seroto (2012) attached teachers' reluctance to use ethnomathematical perspectives to the pressure of having to cover the curriculum within a limited time. The CAPS curriculum, characterised by rigid timeframes in the form of pacesetters (Van der Walt et al., 2019; White et al., 2019), make it difficult for teachers to integrate ethnomathematics to contextualise mathematics. In other words, the mathematics curriculum contents are too broad for the time allocated (Sunzuma, 2019). The contention is that teachers tend to drill learners on rote examination procedures as introducing ethnomathematical perspectives will consume too much of the limited teaching time (Mbusi, 2011; Naresh, 2015). In other words, the main objective for many teachers is to get their learners to pass assessments that are not based on learners' indigenous knowledge (Lebakeng, 2014; Sunzuma & Maharaj, 2021). This has however shown negative results both on the national (ANA) and international assessments (TIMSS), as discussed previously. Mathematics learning should focus on how to apply information to various experiences rather than on how to memorise concepts and procedures to pass an examination. Also, the majority of mathematics teachers do not realise the benefits of ethnomathematics as a teaching approach (Naresh, 2015). Thus, teachers miss valuable contributions from learners' sociocultural or everyday contexts, and how learners' development of mathematics can be influenced by such contexts. However, the aspect of time "[needs] to be addressed alongside the general matters of teaching strategies" (Nkopodi & Mosimege, 2009, p. 379). Among the possible reasons for these contentions is that teachers need to prepare their lesson planning thoroughly on how to maximise the use of ethnomathematical perspectives. Hence, Stinson (2004) suggested that teachers should promote a learning environment that embraces learners' cultural contexts to build learners' cognitive skills in learning mathematics.

Furthermore, previous studies have shown that the mathematics textbooks and other curricular materials have neglected learners' indigenous knowledge contexts (Madusise, 2020; Sunzuma, 2019; Sunzuma & Maharaj, 2021). Madusise (2020) conducted an analysis of learners' mathematics textbooks and found insufficient local cultural mathematical knowledge content but rich implementation ideas from foreign cultures. Masola (2010) also stressed that prescribed mathematics textbooks are neither written in indigenous languages nor illustrated in indigenous contexts. The contention is that a lack of cultural or everyday practices in the mathematics textbooks limit possibilities of integrating ethnomathematics.

In addition, cultural diversity has also been identified as a factor that could hinder integration of ethnomathematics in mathematics classrooms. This challenge stems from the fact that South Africa is characterised by cultural diversity (Brits et al., 2016; De Beer & Mothwa, 2013), as are mathematics classrooms which are characterised by learners from diverse cultural backgrounds (Machaba & Dhlamini, 2021; Sunzuma, 2019; Sunzuma & Maharaj, 2020; Van der Walt et al., 2019). Moreover, the culture of the teachers may not necessarily be the same as that of their learners (Moloi, 2016). The contention is that cultural diversity may hinder integration of ethnomathematics as mathematical ideas and procedures vary from one culture to the other (Gerdes, 2001). As a result, in a multicultural classroom it is necessary for teachers to appreciate that multiple perspectives exist within diverse cultures and within individual learners. In particular, Brandt and Chernoff (2015) suggested teachers should take precautions to ensure that there is a balance of cultures represented in the curricula. Moreover, teachers should look over and analyse the proper activities from different cultural backgrounds, then find the activities that are appropriate to be integrated into the classroom and create a really rich and inspiring environment to help learners develop their potential (Gerdes, 2001). Failure to do so might be problematic for learners as some might think that the contexts being used are different from their own and do not make sense. In order to address this challenge, Nkopodi and Mosimege (2009) urged that when an indigenous game from one culture is used in the classroom, teachers should teach learners the rules of the game and how it is played. Hence, Van der Walt et al., 2019 found that PoP may be a useful pedagogy to address cultural diversity.

There have been several research studies in the literature reporting on technology as one of the key factors that could hinder the incorporation of ethnomathematics in mathematics classrooms (Chahine et al., 2013; Hidayat et al., 2020; Sunzuma & Maharaj, 2019). For instance, Hidayat et al. (2020) noted that technological development makes culture more forgotten. According to Chahine et al. (2013), resistance towards integration of ethnomathematics could be attributed to the preconceived belief related to the nature of IKS as being backward and a push away from technological progress. Consequently, Utete et al. (2019) argued that modern sciences (in this case technological developments) impede the development of IKS. The contention is that preference may be given to technological approaches rather than ethnomathematics which depends largely on cultural contexts that may be considered outdated.

On the contrary, researchers such as Kurniawan et al. (2021) argued that ethnomathematics can be integrated with technological pedagogies to promote a problem-based learning model. Along the same line, Sutarto et al. (2022) conducted a study which sought to develop an effective ethnomathematics-based E-Module to improve students' ability to conjecture with regard to object configuration. As a result, technology developments may provide opportunities for the integration of ethnomathematics in classrooms to circumvent learners’ challenges in learning mathematics. While technology may be seen as a challenge to ethnomathematics, technology can also provide opportunities for integration of sociocultural contexts (Rosa & Orey, 2015). Likewise, Johnson et al. (2022) carried out a study to develop technology-based learning that integrated Emirati culture from ethnomathematical perspectives. Thus, it can be argued that both technology and ethnomathematics can be intertwined as instructional strategies.

As with studies that focused on ethnomathematical perspectives in the classroom, the above-mentioned challenges are limited to primary and secondary schooling. In engagement with the literature to find teacher educators' and student teachers' challenges in pre-service Mathematics teacher education in South Africa, the current research found none (this however does not necessarily mean they do not exist). It is within this context that the current research intended to investigate affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at the selected universities in South Africa.

2.6.9 Ethnomathematics and its role in decolonisation of curriculum

According to Ki-Zerbo (1990, cited in Gerdes, 2014, p. 82), "Africa is in serious trouble, not because its people have no foundations to stand on, but because ever since the colonial period, they have had their foundations removed from under them." Ki-Zerbo's view is still relevant even in education foundations of democratic states such as South Africa. In particular, Kallaway (1988, cited in Msila, 2020) argued that the main goal of colonial education was to impede the development of African learners by distorting curriculum knowledge to ensure domination over the intellect of both the learners and their teachers. This suggests that the colonial education intent was to colonise the mind of the African people through a curriculum to maintain its Eurocentric knowledge as predominant. Thus, colonial education served as an obstacle to hinder the progress and development of African learners in schools and beyond. Regrettably, almost three decades later, the colonial education legacy still prevails in democratic curriculum foundations. Curriculum epistemologies and knowledge have not noticeably changed as they remain entrenched in colonial, apartheid and Western worldviews, and epistemological traditions (D'Ambrosio & Rosa, 2017; De Beer & Mentz, 2019; Heleta, 2016; Le Grange, 2016; Msila, 2020).

Colonial education presented mathematics generally as something rather "western" or "European", as an absolute creation of "white men" (Gerdes, 2014, p. 31). Western mathematics is unequivocally integrated with conquest and colonialism that came to dominate the entire world (D'Ambrosio & Rosa, 2017; Gerdes, 2014; Raju, 2017). As a result, the political and pedagogical trend of ethnomathematics stems from a conscious protest against the colonial structures that imposed and maintained Eurocentric values and number systems (Tun, 2014). The contention is that Western mathematics does not acknowledge contributions of other cultures towards the development of mathematics. In the pursuit to dominate the entire world, mathematics was colonised and, as a result, a perception that white men created mathematics became dominant. D'Ambrosio (1985) further illustrated the suppression of other cultures by arguing:

> In many cases it never gets formalised, and the practice continues to the culturally differentiated group which originated it. The mechanism of schooling replaces these practices by other equivalent practices which have acquired the status of mathematics, which have been expropriated in their original forms and returned in a codified version. (p. 47)

Therefore, there is a greater need to acknowledge and restore mathematical contributions of other cultures.

The rise of the #RhodesMustFall and #FeesMustFall movements in 2015, characterised by students' protests in South African universities, opened robust calls towards transformation and decolonisation of the education curriculum (De Beer & Mentz, 2019; De Beer & Petersen, 2016; Msila, 2020; Ntloedibe, 2019; Seehawer, 2018). Ntloedibe (2019) maintained that #RhodesMustFall has "significantly reinvigorated Steve Biko's ideas on education, African culture and the transformation of South African education" (p. 64). Along the same line, Msila (2020) argued that the call "to decolonise basic education is a call to free and meaningful African education that instils knowledge that would compete equally with other (Western) knowledges" (p. 5). In Tshimpaka's (2018) view, decolonisation is important because the way knowledge production takes place does not address many of the developmental aspirations, challenges and needs of indigenous people. However, Sayed et al. (2017) suggested that decolonising the curriculum is more than an event but a collective deliberation process. There is therefore a need to provide intellectual space for different actors to come together and think deeply about the meanings and processes that saturate their worlds.

According to De Beer and Petersen (2016), African epistemologies are a starting point in decolonising the curriculum. Raju (2017) noted that decolonisation legitimises an epistemological paradigm shift towards integrating indigenous knowledge systems in the teaching and learning of mathematics. Similarly, D'Ambrosio and Rosa (2017) asserted that ethnomathematics seeks to advance peace by building a civilisation which does not discriminate and undermine other systems of knowledge. Thus, mathematics should promote and reflect diverse cultural backgrounds. In other words, there are no superior or inferior cultures in the development of mathematics. Indigenous cultural practices and knowledge should be given a place in the teaching and learning of mathematics. Ethnomathematical perspectives are central to decolonisation of the mathematics curriculum as they recognise multiple and diverse types of mathematics within cultural practices.

Furthermore, Bhuda and Pudi (2020) contended that teacher education ought to realise the influence of ethnomathematics as a methodology for decolonising mathematics. The contention was that decolonising the mathematics curriculum and teaching start with teacher education. Thus, it is essential for teacher education to equip student teachers with decolonisation pedagogies such as ethnomathematics so that they are in a better position to contribute towards decolonisation of the mathematics curriculum. What can be understood from Bhuda and Pudi's (2020) argument is that student teachers should be trained in the epistemologies behind mathematics embedded in sociocultural practices. Hence, Iseke-Barnes (2000) earlier maintained that ethnomathematical perspectives as a decolonising approach are important to teachers who are compelled to examine colonial practices, in order to reveal and counter them. In this regard, student teachers need to be equipped with anti-colonial epistemologies to be able to counter colonial epistemologies.

Similarly, Rosa and Orey (2016) recommended that ethnomathematical perspectives situated in cultural contexts be included in the mathematics curriculum to ensure better teaching and learning and understanding of mathematics, both subject matter and pedagogical content knowledge. In other words, ethnomathematics could contribute towards radical rethinking of western epistemologies and exploring possible ways of decolonising the teaching and learning of mathematics. In Moloi's (2020) view, decolonisation of mathematics could provide learners and teachers with access to hidden knowledge of learning and teaching mathematics. Ethnomathematics, as shown above, offers practical ways through which learners' cultural backgrounds could be used in the teaching and learning of mathematics. While in this study I agree with the notion of decolonising the mathematics curriculum, I agree with De Beer and Mentz's (2019) notion that the integration of African epistemologies should be considered from a learning perspective based on the advances in neuroscience. As result, in this study I argue the affordances of ethnomathematics from an ESDC perspective rather than political stances of decolonisation (as discussed later in Chapter 3).

2.6.10 Criticisms of ethnomathematics

Regardless of the benefits of ethnomathematics in the teaching and learning of mathematics, there are criticisms which point out the weaknesses related to ethnomathematics pedagogy (Domite & Pais, 2009; Horsthemke & Schäfer, 2006; Pais, 2011). Domite and Pais (2009, p. 1473) identified two categories of criticisms of ethnomathematics: epistemological and educational or pedagogical. On the one hand, epistemological criticism focuses on the way ethnomathematics positioned itself in terms of mathematical knowledge. Rowlands and Carson (2002) argued that the "bottom-up" curriculum advanced by ethnomathematics pedagogies, where learners interpret and apply context from their everyday lives to solve problems, minimises formal academic mathematics as a discipline with an abstract body of knowledge. Rowlands and Carson's (2002) criticisms indicate that they perceive mathematics from the traditionalist view.

On the other hand, educational or pedagogical criticism focuses on the way ethnomathematical ideas are implicated in formal education. Rowlands and Carson (2002) have warned that there is every danger that mathematics as an academic discipline will become accessible only to the most privileged in society while the rest learn multicultural arithmetic within problem solving as a life skill or merely venture into geometric aesthetics. Therefore, the integration of ethnomathematical ideas in the teaching and learning of mathematics could curtail access to academic mathematics. Furthermore, Rowlands and Carson (2002) maintained that mathematics can be taught effectively and meaningfully without relating it to culture. Pais (2011) contended that critics are against the use of ethnomathematical pedagogies in the mathematics classroom because there may be incommensurable ways of understanding and perceiving mathematics. Moreover, Rowlands and Carson (2002) pointed out that mathematics is a foreign language to all children regardless of their cultural backgrounds, so they are probably not at any significant disadvantage when it comes to learning mathematics. These critics suggest that mathematics found in various cultural practices should not be part of school mathematics. The critics have further asserted that the classroom should be a place to learn academic mathematics.

Horsthemke and Schäfer (2007) argued that ethnomathematics has a limited scope to qualify as a pedagogical or epistemological tool since it focuses on an identified cultural group, where the learners could relate to the cultural context used as a point of reference. These authors suggest that the integration of ethnomathematics may not necessarily promote access to western mathematics. In this sense, learners who are not familiar with cultural backgrounds from other cultural groups are likely to feel excluded in the learning process. Thus, the introduction of ethnomathematical ideas in school can function as a factor for exclusion because, whereas the learners from the ‘dominant culture’ continue to learn the academic mathematics that allows them to compete in a more and more mathematised world, learners from other cultures will only learn a local and rudimentary knowledge that scarcely contributes to their emancipation (Pais, 2011).

The above critics reveal that the role of ethnomathematics may be oversimplistic. In this regard, learners may focus on contextual aspects of a problem embedded in the context rather than on the salient mathematical concepts (Metz, 2013). Furthermore, introducing problems embedded in sparse contexts may be too abstract, not interesting to many students, and detached from their everyday experience (Mevarech & Stern, 1997). In other words, contexts that are unfamiliar or non-meaningful to students may have a negative effect on their learning. Herein, contexts can be considered as distractors or barriers to mathematical understanding. Thus, not every context may be relevant in the teaching and learning of mathematical concepts.

2.7 PRE-SERVICE TEACHER EDUCATION: STUDENT TEACHERS' PROFESSIONAL DEVELOPMENT

Pre-service teacher education is generally offered in universities and is characterised by developing students who aspire to become teachers. In other words, it focuses on education of teachers before they enter into service as teachers. Student teachers enter their pre-service education with 12 or more years of schooling experiences and perceptions about teaching profession influenced by their teachers (Mentz & De Beer, 2020; Petersen et al., 2020). As a result, it is important for pre-service teacher education to correct, refine, and build on some of the experiences that student teachers bring to their training as teachers. To this effect, Petersen et al. (2020) have warned from 'apprenticeship of observation' (as often referred to by Lortie, 1975), that failure to transform perceptions about pedagogical orientations will result in student teachers imitating the way they were taught at school. Thus, student teachers' philosophies and knowledge about teaching and learning of mathematics are reshaped and developed during pre-service teacher education. This suggests that the professional developments, dispositions, and self-identity of students as teachers are a focal point in pre-service teacher education.

Ideally, all pre-service teacher education at universities aspires to produce knowing, caring, and committed reflective practitioners (Mentz & De Beer, 2020; Sosibo & Nomlomo, 2014; Taylor, 2014; Van Wyk, 2014). However, reality has shown that pre-service teacher education is not sufficiently equipping student teachers to meet the demands of the teaching profession (Mentz & De Beer, 2020; Ramsaroop & Gravett, 2017). In addition, government's own investigation into the quality of pre-service teacher education and recent research makes it clear that the quality of most of these programmes leaves a lot to be desired (Hofmeyer, 2015). Hofmeyer's report suggests that some of the teacher education programmes might not be meeting prospective teachers' practical teaching needs. It implies that most of the pre-service teacher education programmes are not sufficiently equipping or preparing student teachers for the teaching needs and demands of the profession. Hence, the Draper et al (2017) in their CDE 2017 report noted that most teachers are underprepared for teaching. It is therefore necessary to focus on pre-service teacher education because "the cause of poor teaching lies not with teachers but with the teacher education system that produced them" (Taylor, 2014, p. 4).

2.7.1 Minimum Requirements for Initial Teacher Education Qualification

The Minimum Requirements for Teacher Education Qualifications (MRTEQ hereafter) provides a basic framework for Initial Teacher Education (ITE) or pre-service teacher programmes that accredited institutions must use as a guide to develop teacher education qualifications. It gives clear, specific requirements for the development of learning programmes and guidelines regarding practical and teaching practice (TP) or work-integrated learning (WIL) structures (DHET, 2011, 2015). The main aim of MRTEQ is to ensure that the higher education system produces adequately prepared teachers who will be responsive to the needs of the country. In this regard, there is a need for ITE to address the essential challenges confronting education in South Africa. In order to address essential challenges, MRTEQ stated that newly qualified teachers should possess the following set of knowledge competences: sound subject knowledge; pedagogical content knowledge; learners' knowledge; communication skills; developed literacy, numeracy and Information Technology (IT) skills; knowledge of school curriculum; understand diversity in the South African context; classroom management skills; knowledge of assessment; positive work ethic and display appropriate values; and critical reflection.

Furthermore, MRTEQ provides teaching specialisations for pre-service teacher education qualifications in accordance with the SADBE which consists of the following phases: Foundation Phase (Grades R-3); Intermediate Phase (Grades 4-6); Senior Phase (Grade 7-9); and Further Education and Training (FET) Phase (Grades 10-12). Hence, pre-service teacher education offers Bachelor of Education (BEd) degrees, which consist of various programmes according to areas of specialisation in all phases of school learning. Student often choose two school subjects they will be majoring in.

The BEd degree is generally a four-year programme across the institutions. During this duration, student teachers are prepared in various learning programmes, which focus on subject content and methodology or pedagogy modules. However, the contents of learning in pre-service teacher education vary widely among institutions (Taylor, 2014). Each university or institution offering pre-service teacher education is autonomous in developing and determining learning programmes and how they will be realised. As a result, universities draw from different theoretical foundations to design their pre-service teacher education curricula (Kwenda & Robinson, 2010; Lebeta, 2006).

During the BEd training, student teachers, who chose to major in mathematics, are required to take courses that deal specifically with mathematics content as well as methodology courses. On the one hand, the mathematics content courses help student teachers to develop mathematics content knowledge. It is important for student teachers to have sufficient knowledge about mathematics, its principles, theories, and conjectures, amongst other mathematical aspects. This will help them develop confidence in their mathematics classrooms. On the other hand, the methodology courses empower student teachers with theoretical underpinnings that relate to the teaching and learning of mathematics. The focus on methodology courses is on equipping student teachers with pedagogical knowledge and skills. It equips them with knowledge pertaining to the how of teaching mathematics, by focusing on various teaching strategies such as collaborative learning and IBL, as discussed in Chapter 2. A focus on teaching strategies exposes student teachers to a variety of strategies they can implement to make mathematics accessible by the learners in their prospective mathematics classrooms. This will ensure student teachers select appropriate strategies that are relevant to teach particular topics in mathematics.

In addition to theoretical learning, there is a component of WIL in pre-service teaching education programmes. There is agreement amongst researchers that WIL has the strongest impact on teaching and is an integral aspect of all teacher training and preparation (Green, 2020; Masood et al., 2022; Roness, 2011; Singh & Singh, 2012). The concept of student WIL is globally premised on preparing pre-service teachers to work in diverse schools and learner populations (Matoti & Odora, 2013; Nkambule & Mukeredzi, 2017). WIL provides opportunities for student teachers to experience the complex nature and richness of the realities of teaching in actual classrooms. The essential role of WIL is further evident in the Council on Higher Education’s (CHE) *Report on the Review of Academic and Professional Programmes in Education* (CHE, 2010) which underscored that the success of a teacher education programme is central to WIL. Thus, student teachers are provided with the chance to experiment and test their pedagogical content knowledge and skills in the classroom, and also reflect on their mistakes and develop their own teaching identities (Abongdia et al., 2015; Dorasamy, 2018; Green, 2020; Hill, 2021; Mentz & De Beer, 2020; Singh & Singh, 2012). The suggestion is that during WIL student teachers are expected to put into practice the theoretical aspects learned in the modules.

Although WIL is considered as an integral part of student teachers’ professional development, Kiggundu and Nayimuli (2009) considered it as a break or make phase for student teachers. Kiggundu and Nayimuli’s (2009) argument suggest WIL enables student teachers to develop confidence, motivation, and attitude. The experiences and knowledge they gain during teaching practice can have a huge impact as future teachers. The manner in which they interact with learners in the classrooms, how they deal with issues related to learners’ discipline can at times be overwhelming. It can further be opined that the experiences expose student teachers to the realities of teaching and learning in diverse settings. Hence, it is important that they receive all the necessary support during teaching practice. Thus, they should begin to see teaching practice as a learning opportunity for their professional growth as mathematics teachers.

2.7.2 Challenges in pre-service teacher education

Although the main aim of pre-service teacher education is to prepare student teachers to be well-equipped teachers, there are numerous challenges that often arise in pursuit of such aim. The following challenges are discussed: Low admission requirements, culture of the school, lack of support during WIL, and mismatch between theory and practice.

2.7.2.1 Low admission requirements

There is a concern that pre-service teacher education in programmes in South Africa have low entrance requirements in comparison with most other disciplines. For example, Taylor's (2014) report revealed students in some institutions are permitted to specialise as mathematics teachers even if they scored as low as 30% on Mathematical Literacy in the National Senior Certificate. The government Ministerial Report on Teacher Education has also noted that many students in initial teacher education programmes have very poor levels of literacy and numeracy (SADBE, 2005). Thus, it appears that weaker students may be attracted to the BEd programmes.

In addition, students are admitted without any in-depth interviews about their motivation to become teachers. This is different from other countries where entrance tests of universities are used to assess aspects such as academic studying skills and aptitude for the teaching profession. The Finnish student teachers, unlike in South Africa, are orientated in research. Lauriala (2013) underscored this by saying that in Finland, a two-year master's degree programme was added to the three-year primary school teacher diploma in 1979. For Loughran (2007), this strongly suggested that teacher education in Finland is based on the prospective teacher as researcher approach, which involves researching practice and constructing personal, principled knowledge, and strategies. Taylor's (2014) report also revealed that in some institutions, the focus appears to be on quantity (more teachers) rather than quality (better teachers).

2.7.2.2 Culture of school during work-integrated learning

Another challenge relates to the culture of schools student teachers found themselves in during WIL. Despite student teachers having a choice for their placements, they could not always be placed at schools that emulated good school management practices (Matoti & Odora, 2013). Mawoyo and Robinson (2005) underscored this by saying that students often chose schools close to where they live as opposed to a school that would provide them with a teaching practice experience where they could learn well. Thus, they are often placed in under-resourced, overcrowded classrooms and, at times, dysfunctional schools. These factors often make it difficult for student teachers to employ their theoretical knowledge gained from the universities (Modipane & Kibirige, 2015).

Furthermore, student teachers often find themselves in schools characterised by learners' lack of discipline during WIL. Marais and Meier (2004) earlier indicated that student teachers experienced a deterioration of moral values, lack of discipline, and violence in schools as a common reality. The lack of discipline has escalated to a point where learners attack student teachers in the classrooms. The lack of these essential attributes, as identified by Marais and

Meier (2004), may have the potential to destroy student teachers' confidence and identity formation in their journey to becoming a teacher. Similarly, Kiggundu and Nayimuli (2009) found that discipline was almost non-existent in most schools. For Modipane and Kibirige (2015), this lack of discipline among learners could unsettle student teachers. Although Modipane and Kibirige (2015) pointed out the impact of learners' discipline on student teachers, it may also provide student teachers with opportunities to demonstrate their classroom management skills. Hence, Masood et al.'s (2022) findings indicated that student teachers learn to manage behaviour of their learners verbally and also use different reinforcement strategies to promote learners' good behaviour.

2.7.2.3 Lack of mentor teachers' support during work-integrated learning

Student teachers often find mentor teachers unsupportive during WIL, as they often shift responsibilities to them. In this regard, Modipane and Kibirige (2015) found that many students revealed that their presence in schools during WIL is often a relief to some in-service teachers. Similarly, Kiggundu and Nayimuli (2009) reported that student teachers ended up taking full loads, while mentoring teachers took a back seat. The contention is that student teachers tend to be overloaded by mentoring teachers who are supposed to guide them. Moreover, when student teachers are placed in schools for WIL, they often lack support from their mentoring teachers. Nkambule and Mukeredzi (2017) revealed that some mentor teachers appeared uninterested in assisting students. Likewise, Marais and Meier (2004) earlier argued that mentor teachers did not always devote enough time and attention to student teachers. Student teachers also felt that mentoring teachers often failed to provide them with support and skills regarding the actual teaching in the classrooms (Modipane & Kibirige, 2015). Among the possible explanations for these assertions is that student teachers' identity formation is likely to be hindered because of the mentor teachers' lack of support.

However, not all mentors are unsupportive. For example, Nkambule and Mukeredzi (2017) and Kiggundu and Nayimuli (2009) noted that the mentors were found to be positive, always willing to assist, guide and offer valuable advice, and shared their skills and experiences with students. The mentor teacher played an important role in assisting the quality of pre-service teachers' learning experiences and development of MCK for teaching (Livy et al., 2016). In other words, teachers should facilitate learning by guiding student teachers when they are planning lessons; observing pre-service teachers teaching; providing feedback after the lesson; as well as modelling good practice when teaching primary mathematics (Livy et al., 2016). Thus, student teachers need mentors who can provide examples of good practice for them to evaluate and emulate in their classrooms. The inclusion of mentoring training by the universities would assist to prepare mentor teachers to deal with the challenges experienced by student teachers during WIL.

2.7.2.4 Mismatch between theory and practice

A plethora of literature shows a general agreement that a gap exists between theory and practice in education. For instance, it has been documented that theory learnt as part of pre-service teacher education programmes is largely divorced from the reality of student teachers' experience in the classroom (Gravett et al., 2014; Monroe et al., 2010; Roth et al., 2014). These authors insinuate that the theories student teachers learn may have little to do with the classroom realities. The contention is that pre-service teacher education does not adequately prepare student teachers to deal with the multifaceted classroom realities. Among the plausible explanations for these assertions is that theories in pre-service teacher education programmes should align with contexts in which teaching practices exist. In so doing, student teachers could see how theories could be used to better comprehend classroom realities.

2.8 CHAPTER SUMMARY

In this chapter, I discussed the literature review which gives this study significance and relevance. I focused amongst others on the status of mathematics performance in South Africa, which reflects a worrying trend of learners' underachievement. I also focused on ethnomathematics, what research reveals about it and why it is necessary to prepare student teachers to use this recent innovative instructional pedagogy in the teaching and teaching of mathematics, Furthermore, a focus on numerous studies on ethnomathematics not only helped me to locate an existing gap in the literature, but also provided an insight into the theoretical and conceptual framework as well as methodological aspects as described respectively in the next two chapters.

CHAPTER 1

- BACKGROUND AND CONTEXT OF THE STUDY

CHAPTER 2

- LITERATURE REVIEW

CHAPTER 3

- THEORETICAL AND CONCEPTUAL FRAMEWORKS

CHAPTER 4

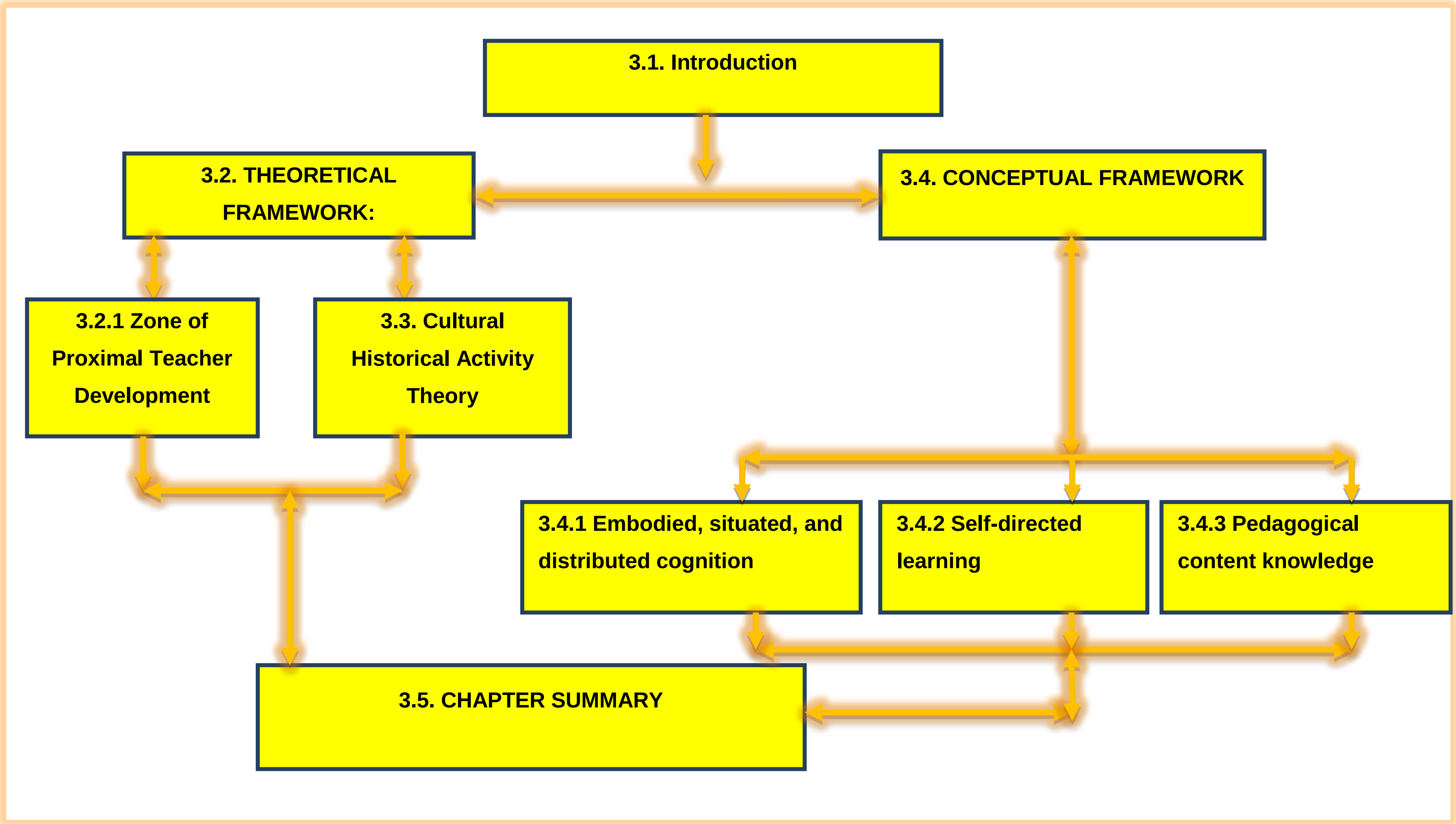
- RESEARCH DESIGN AND RESEARCH METHODOLOGY

CHAPTER 5

- PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

CHAPTER 6

- MAJOR FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION


3.1. Introduction
3.2. THEORETICAL FRAMEWORK:
3.4. CONCEPTUAL FRAMEWORK
3.2.1 Zone of Proximal Teacher Development
3.3. Cultural Historical Activity Theory
3.4.1 Embodied, situated, and distributed cognition
3.4.2 Self-directed learning
3.4.3 Pedagogical content knowledge
3.5. CHAPTER SUMMARY

CHAPTER 3

THEORETICAL AND CONCEPTUAL FRAMEWORKS

3.1 INTRODUCTION

In this chapter, I build on the comprehensive literature foundations presented in the previous chapter by addressing the theoretical and conceptual frameworks underpinning the research study. It is important to make a distinction between these concepts as they are often viewed synonymously (e.g., Maxwell, 2005, 2013; Saunders et al., 2015) or diversely (e.g., Maxwell, 2012). In the context of my study, the concepts are differently viewed. Consequently, I am most drawn to the idea of a theoretical framework as "a structure that guides research by relying on a formal theory…constructed by using an established, coherent explanation of certain phenomena and relationships" (Eisenhart, 1991, p. 205). Thus, it presents a theory which can be used for a "set of explanatory understandings that help us make sense of some aspect of the world" (Brookfield, 2005, p. 3). The contention is that the theoretical framework provides a frame through which the phenomenon under investigation can be understood. As a result, Vygotsky's sociocultural theory served as a theoretical framework.

On the other hand, conceptual framework as used in my study refers to "an argument about why the particular topic one wishes to study matters, and why the means proposed to study it are appropriate and rigorous" (Ravitch & Riggan, 2017, p. 5). The role of conceptual framework in my study is to show the relationship of the different constructs and how they relate to this research study. Thus, in this section I focus on the relationship between ethnomathematics and various intermediate theories (as often referred by Engeström) such as ESDC, SDL, and PCK.

3.2 THEORETICAL FRAMEWORK: SOCIOCULTURAL THEORY

For better understanding of the affordances of ethnomathematical perspectives in pre-service mathematics teacher education, sociocultural theory was adopted. Sociocultural theory is, according to Vygotsky (1978), a learning theory that considers student teachers' social and cultural contexts as their entry points to learning. Thus, the choice of sociocultural theory in this study is on the premise that, as with ethnomathematics, it acknowledges and promotes the role of social, historical, and cultural practices in the teaching and learning of mathematics. From Vygotsky's point of view, environmental factors such as cultural practices are essential to understanding cognitive development in a learning process. The argument is that student teachers' professional development based on their cultural practices will not only assist them to learn and understand mathematics, but to teach it in an accessible manner in their prospective classrooms using tools, signs, and symbols drawn from such practices. Thus, ethnomathematics provides an excellent example of how learning takes place in a cultural practice. Therefore, it is necessary to be well-prepared and knowledgeable in order to successfully mediate the integration of learners' cultural practices through ethnomathematics into their lessons.

Vygotsky's (1978) sociocultural theory further highlights that student teachers' learning, and development can be understood as deeply rooted at two levels, namely the social level (interpsychological) and the individual level (intrapsychological). Vygotsky (1978) argued that "every function in the child's cultural development appears twice; first, on the social level, and later, on the individual level -- first, between people (interpsychology), and then inside the child (intrapsychology)" (p. 57). On the one hand, the interpsychological level is characterised by social interaction with others (2013; Pieterse & Stallmann, 2014; Schunk, 2016), such as how teacher educators prepare student teachers towards contextualising mathematics by infusing ethnomathematics. Basically, Vygotsky's implication is that new knowledge can be formed through social interactions "with others before being integrated into one's own mental structure" (Potgieter, 2020, p. 46). The student teachers' professional development is socially and culturally situated as student teachers interact with other individuals such as teacher educators within contexts of collaborative environment in pre-service teacher education training. The implication is that student teachers will value the importance of social interactions in the learning of mathematics in their prospective classrooms.

In Vygotsky's view, a socially situated view of student teachers' development outlines the movement of pedagogical knowledge between the social level and the individual level. This movement across the social and individual level is understood to be the zone of proximal development (ZPD). Vygotsky (1978) introduced the notion of ZPD as "the distance between the actual development level as determined by independent problem solving and the level of potential developments as determined through problem-solving under adult guidance or in collaboration with more capable peers" (p. 86). Simply put, "The ZPD measures the distance between what a learner is able to do and a proximal level that they might attain through the guidance of an expert-other" (Warford, 2011, p. 252). While Vygotsky's notion of ZPD is central to understanding learning processes, it is in Warford's Zone of Proximal Teacher Development that this study looks at the professional development of student teachers towards integrating ethnomathematics in the classrooms.

3.2.1 Zone of Proximal Teacher Development

Although Warford (2011) agreed with Vygotsky' s (1978) definition of ZPD, he believed that it has limitations on how it can be applied in the context of teacher development. As a result, Warford (2011, p. 252) refined Vygotsky's ZPD concept "to educating teachers within Zone of proximal teacher development (ZPTD)" from sociocultural theory perspectives. Warford (2011) defined ZPTD as the distance between what the teachers, in this case student teachers, can do on their own without assistance and a proximal level they might attain through strategically mediated assistance from more capable others such as teacher educators. It is in Warford's ZPTD that I considered it necessary for student teachers (only at University C) to be exposed to an ethnomathematics intervention workshop (discussed in detail in Chapter 4), where they received guidance from more knowledgeable facilitators to help them with necessary knowledge and skills to integrate ethnomathematics in their prospective classrooms. Thus, the ethnomathematics intervention workshop served to scaffold student teachers' actual development to their potential development.

While researchers such as Van der Stuyf (2002) posited that the result of scaffolding is not permanent during the learning of the new concepts, the aim of the ethnomathematics intervention workshop was to help student teachers to develop pedagogical knowledge and skills to integrate ethnomathematics into their prospective classrooms. Moreover, the intention was to help them to become autonomous and self-directed learners who can find relevant ways to integrate ethnomathematics in their unique settings. Research has shown that workshops are effective in developing pedagogical approaches which can promote epistemological border-crossing connecting mathematics and ethnomathematics (Van der Walt et al., 2019). There is a need to prepare student teachers in ethnomathematics because, as argued by Vygotsky (1986),

> direct teaching of concepts is impossible and fruitless. A teacher who tries to do this usually accomplishes nothing but empty verbalism, a parrotlike repetition of words by the child, simulating a knowledge of the corresponding concepts but actually covering up a vacuum. (p. 150)

Thus, it is my contention that the pedagogies that student teachers learn through participating in an ethnomathematics intervention can empower them to contextualise mathematics. By so doing, their mathematics classrooms become learner centred instead of characterised by direct teaching.

Furthermore, this study shared the same view as Warford (2011), who argued that teaching teachers from Vygotsky's perspective is characterised by a three-way discourse influenced by student teachers' prior experiences as learners and beliefs about teaching, pedagogical content of the teacher education programme, and observations of teaching and learning during WIL learning placements. The experiences student teachers bring into their pre-service teacher education are a starting point towards their development as teachers. Warford further indicated that there must be an amalgamation between field-based and academic-centred concepts in order to promote student teachers' development. As a result, situated learning within a Vygotskyan context blends the scientific discourse of the university classroom with the experiential discourse of school classrooms (de Beer, 2017; Warford, 2011).

Warford (2011) elaborated the notion of ZPTD by outlining four stages which are necessary for scaffolding student teachers' learning towards their development: self-assistance, expert other assistance, internalisation, and recursion.

3.2.1.1 Self-assistance

Self-assistance focuses on student teachers' reflections on prior experiences and ideas which shape their pedagogical identities. In this present research study, it was considered necessary first to establish student teachers' prior experiences, knowledge, and preconceived ideas about mathematics and ethnomathematics pedagogies through using a pre-intervention questionnaire and also focus group interviews. According to Mentz and de Beer (2019), "this stage provided an opportunity for [student] teachers to identify personal problems experienced in their teaching and to set their own learning goals accordingly" (p. 53). Warford (2011) considered the self-assistance stage as a starting point towards the student teacher's actual level of development.

3.2.1.2 Expert other assistance

Expert other assistance focuses on the role of the knowledgeable other such as teacher educators or facilitators in assisting student teachers through scaffolding or mediation in their professional development (de Beer, 2017; Warford, 2011). During the intervention, demonstrations of how ethnomathematics pedagogies could be infused to contextualise some of the CAPS mathematics concepts were carried out by the researcher and study leaders. In Vygotsky's language, this stage focuses on scaffolding of student teachers on ethnomathematics approaches by more knowledgeable others, in this case study leaders (intervention facilitators). The facilitators were considered to be experts as they have presented similar workshops focusing on in-service STEM teacher professional development.

3.2.1.3 Internalisation

De Beer (2017) described internalisation as “critical reflection and journaling”, which enable the “student teachers start to develop an own footing and voice, and they slowly develop a more nuanced teaching philosophy” (p. 17) based on ethnomathematics perspectives in contextualising mathematics. Thus, this stage focuses on strengthening and promoting student teachers’ reflection on their pedagogical development (Fani & Ghaemi, 2011; Potgieter, 2020). In this research study, the internalisation stage offered student teachers an opportunity to reflect on their newly gained pedagogical knowledge on ethnomathematics and its implications in mathematics classrooms. This was achieved through student teachers’ focus group interviews conducted after the ethnomathematics intervention. Thus, the focus group discussions in one of selected universities offered the researcher the opportunity to see if student teachers’ pedagogical orientation on ethnomathematics had improved due to the intervention.

3.2.1.4 Recursion

This is the final stage of student teachers’ professional development, characterised by theory-practice processes where student teachers tackle the conflict between theory and practice (Fani & Ghaemi, 2011; Warford, 2011). However, this was not done in this present study due to cancellation of WIL school visits attributed to the COVID-19 pandemic. The focus during this stage is on student teachers’ integrating ethnomathematics in their classrooms during WIL.

Table 3-1: Scaffolding student teachers' learning across the ZPTD during the ethnomathematics intervention

ZPTD stage	Stage description	Activities during the ethnomathematics intervention workshop
Self-assistance	Reflecting on own teaching-learning praxis, recalling prior experiences, needs or problems faced in the mathematics classroom.	Pre-questionnaires were given to student teachers at University C where they reflected on their experiences in the mathematics classroom and pre-service teacher education, including their knowledge and experiences of contextualised mathematics.
Expert-other assistance	The scaffolding of knowledge based on the assistance of a knowledgeable other.	Student teachers at University C engaged in activities such as indigenous games, boomwhackers, multiplication in many cultures facilitated by the supervisors.
Internalisation	Reflection on professional development intervention where attained knowledge and concepts are reviewed and discussed. This stage offered student teachers the chance to strengthen their reflections on their newly gained ethnomathematics pedagogical knowledge.	Student teachers at University C participated in the focus group interviews conducted after the intervention. Thus, the focus group offered the researcher the opportunity to see if student teachers' pedagogical orientation on ethnomathematics had improved due to the intervention.
Recursion	Theory is put into practice and participants are afforded the opportunity to put into effect what they have learnt during the professional development intervention.	This stage was not carried out in the study due to restrictions imposed by COVID-19 on teaching practices at University C. It would have been interesting to observe how student teachers put into practice what they had learnt during the intervention in their actual mathematics classrooms during WIL.

3.3 CULTURAL HISTORICAL ACTIVITY THEORY

Cultural-historical Activity Theory (CHAT) is a framework for systematically analysing human activities in context. According to Kaptelinin and Miettinen (2005), CHAT is “a powerful analytic tool that helps to reveal the fundamental aspects of social practice, and support structured, meaningful interpretations of empirical data” (p. 1). CHAT has been shown to be a useful analytical lens for understanding and representing dialectical transformations that occur between and within activity systems in which individuals or groups (defined as subjects) and their goals or objects are mediated by conceptual and physical tools developed within a community and mediated by shared rules and divisions of labour (Behrend, 2014).

3.3.1 The development of CHAT

CHAT has its roots in the thoughts and ideas of Lev Vygotsky’s sociocultural theory. CHAT was further developed by Leont’ev (1978, 1981) and further conceptualised by Engeström (1987). Vygotsky (1978), who is associated with first generation CHAT, emphasised that artefacts such as cultural tools and language mediate all human action. Vygotsky’s sociocultural theory focused on artefact-mediated action in the activity theory (see Figure 3-1). He emphasised mediated action because of the interaction between subject, tools, and object in order to enable an individual to understand their world (Hardman & Amory, 2015). In other words, our human psychological functioning or human action cannot be understood without including the social, cultural, and historical context in the analysis (Havnes, 2010; Mentz & De Beer, 2017; Postholm, 2015; Yamazumi, 2006). Vygotsky suggested that other people and the cultural-historical context in which we live mediate our relationship with the world. Activity theory, according to Jonassan and Rohrer-Murphey (1999), is premised on the notion that “tools mediate or alter the nature of human activity and, when internalized, influence humans’ mental development” (pp. 66–67). As a result, Vygotsky conceptualised cultural mediation in an attempt to describe how construction of meaning is facilitated by various sociocultural and environmental interactions.

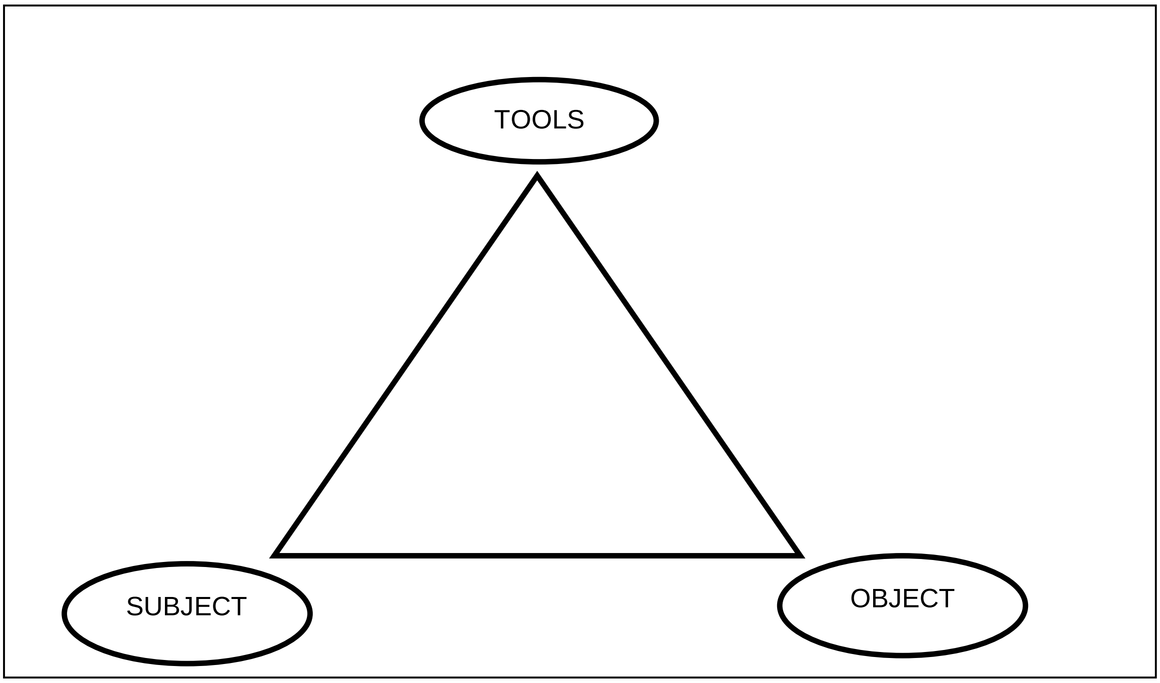


Figure 3-1: Tools mediate between subject and object.
(Adapted from Vygotsky, 1978)

Leont'ev (1978), who is often credited with the formulation of the second generation of CHAT, described activity as a shared meaning amongst its members whereby roles are negotiated within the system. He underscored that learning is a collective activity where collective individuals form part of the activity system (Beatty & Feldman, 2012; Hardman & Amory, 2015; Lupu, 2011). In other words, Leont'ev's (1978) work expanded Vygotsky's activity theory that could not account for activities that involved collective action. To emphasise that activity is socially located and the community around the activity profoundly affects and is affected by the activity, Leont'ev (1978) proposed that we consider the community as a mediator (Figure 3-2). That is, others influence our individual knowledge and meaning in the community.

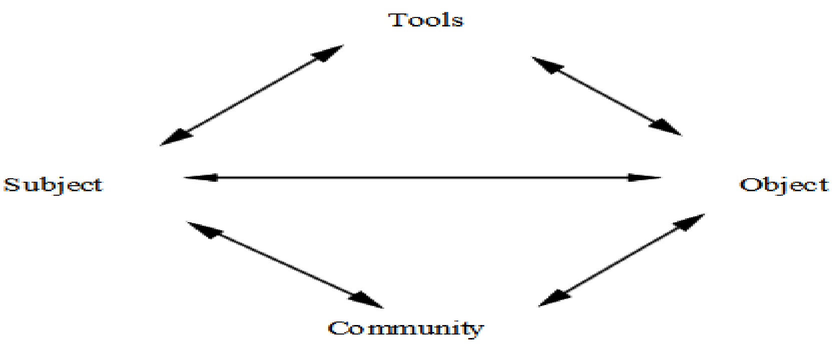


Figure 3-2: Leont'ev's Second Generation Activity Theory

(Source: Clark, 2012, p. 3)

Furthermore, Leont'ev's (1978) main principle is that the activity of human beings is goal-directed, adaptable, and manifests interaction between the actors (subjects) with its world (objects). He illustrated goal-oriented in his three-level hierarchical model of activity theory (Figure 3-3). The first level involves activity, which is established, enhanced, and mainly driven by social interaction within a collective context. The second level focuses on actions, which are understood as goal-oriented that move towards fulfilment of the object (Hardman & Amory, 2015; Rybacki, 2009). The last level focuses on operations, which are unconscious acts that occur within the context of the activity. Operations focus on "the methods for accomplishing actions" (Leont'ev, 1978, p. 65). The final goal is the same, but the roles of the individual members differ. That is, mediation is on relationship with the other components of an activity system (Engeström, 1999, p. 29.). According to Leont'ev (1978), the most important factor in identifying the object of activity is the 'object motive', a particular point of view and set of parallel values that direct the participation of subjects in an activity system (Edwards, 2011). Leont'ev (1981) also contributed the idea that activity systems are directed by a motive, and individual and collective action within that system must be understood in the context of the motive (i.e., object) of the activity system (Tsui & Law, 2007).

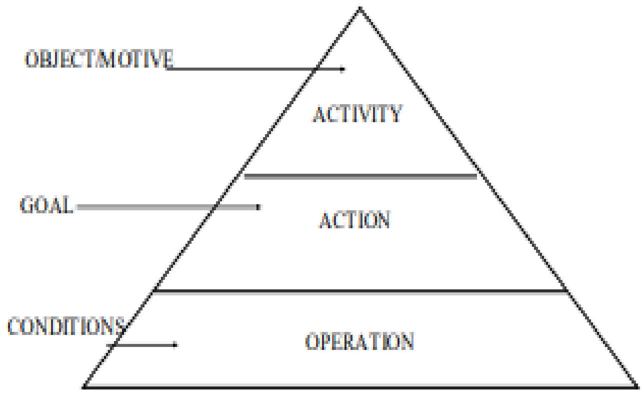


Figure 3-3: Leont'ev activity theory.

(Source: Hardman, 2007, p. 7)

Engeström (1999) further expanded on the scope of Vygotsky's and Leont'ev models to explore the complex relationships between people, mediating artefacts, and behaviour. In this regard, Engeström expanded the human activity system to describe the interconnectedness of an individual's different activities and how social contexts mediate individual thinking. In the expanded version, the rules, community, and division of labour are added to tools, subject, and object to connect with and influence each other to shape the outcome of the activity system.

CHAT provides a lens into the activity system where the focus will be on a subject, object, rules, and community, mediating artefacts (tools) and the division of labour in each activity system. In this study, Engeström's model of second-generation CHAT was adopted as theoretical and analytical foundations as it is used for education discourses and its application in the field of teacher education. Thus, this study wanted to use the second generation Cultural Historical Activity Theory because it involves a single activity system (pre-service teacher education activity system) with collective individuals (student teachers and teacher educators) as indicated in Figure 3-4 below. Engeström's second-generation CHAT illustrates that human cognition, learning, emotion, and volition are socio-historical processes that occur in the context of a culturally mediated activity system, and that the human mind and consciousness are situated, distributed, and shared in an activity system (Yamazumi, 2006).

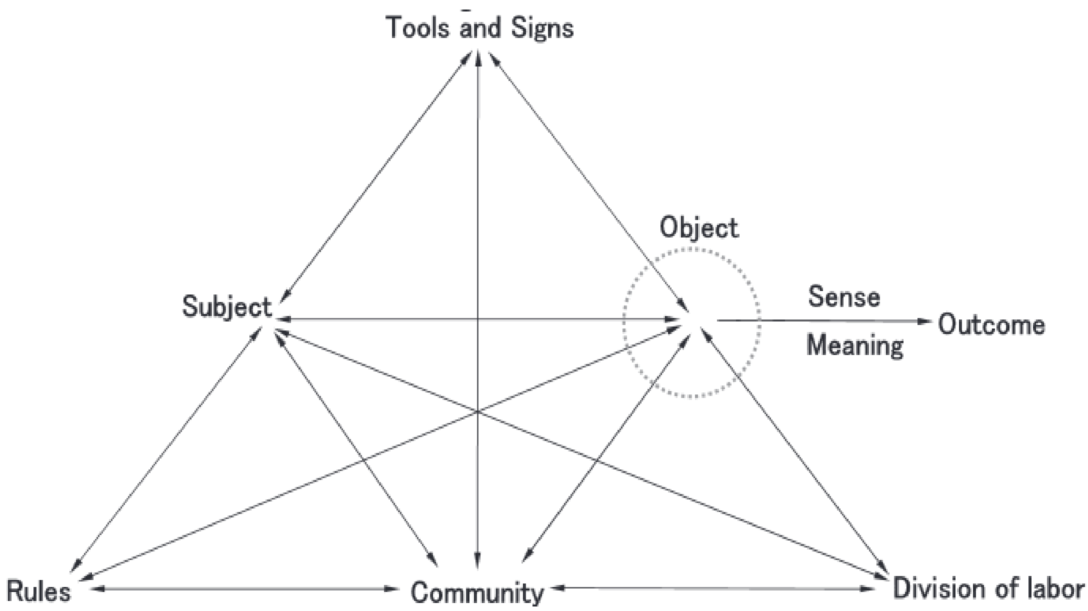


Figure 3-4: Second-generation Cultural Historical Activity Theory framework.

(Source: Engeström, 1987, p. 78)

Engeström's second-generation CHAT reveals the relationship between subject and object as mediated by multiple elements in the activity system. Groon (2002) underscored this relation by illustrating that the arrows between the elements show they are dynamic and continuously interact as a whole. In other words, all the elements of the activity system mutually influence each other to meet their collective goal (Roth & Lee, 2007; Roth & Tobin, 2002; Tsui & Law, 2007). In other words, the Engeström model specifically focuses on the social transformation which includes the structure of the social world in analysis, considering the conflictual nature of social practice. Knowledge is constructed through discourse and interaction between the elements and is a primary focus of CHAT (Timmis, 2014).

Finally, relevant to this study is the third-generation activity theory which Engeström (2001) defined as "a collective, media-artefact activity system, seen in its network relations to the other systems" (p. 136). The suggestion is that an activity system does not function in isolation but as part of a wider network of activities (Hardman, 2015). As a result, the third generation consists of a minimum of two interacting activity systems and focuses on the meaning within individual activity systems and where they intersect (Figure 3-5). According to Engeström (2001), the intersection is an additional unit of analysis and provides an opportunity to explore potential benefits to identify that point of action. Engeström draws on ideas on multiple viewpoints in order to move beyond the limitations of the second generation of activity theory, which was concerned with the analysis of single activity systems (Daniels & Warmington, 2007). Thus, the third generation intends to provide tools and concepts that can enable us to understand and explore multiple viewpoints within interacting activity systems.

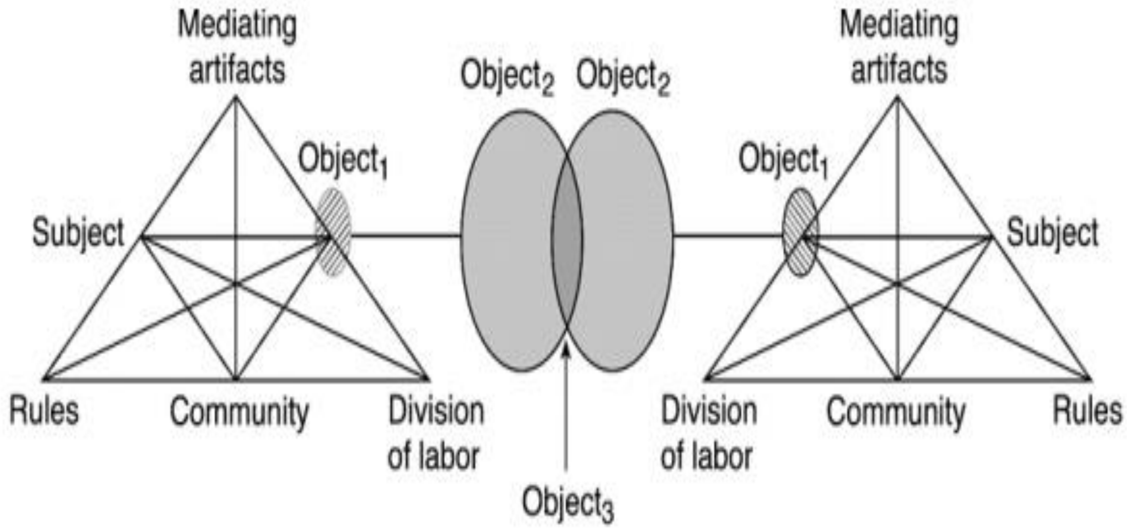


Figure 3-5: Third-generation Cultural Historical Activity Theory framework.

(Adapted from Hardman, 2015, p. 53)

It is essential to define each element of Engeström's third-generation CHAT. *Mediated artefacts (Tools)* mediate the relationship between the subject and the object, what the participants are trying to achieve (Gretschel et al., 2015). Tools can be determined based on the local and historical position or context that help participants of an activity system to carry out an activity (Bravo Olavarria, 2013; Foot, 2014; Leonardo, & Manning, 2017).

Subject refers to the bearer of the activity and can refer to an animate or inanimate individual entity or collective (Lektorsky, 2009). According to Engeström (1987), the subject is oriented to transform some object using a cultural–historically constructed tool (technical or psychological). In addition, subjects have the ability to employ agency depending upon their social position within the situated cultural and historical context (Ogawa et al., 2008). Depending on how CHAT is used, the subject could also be an institution or system rather than an individual or a group (Mentz & De Beer, 2017). The view is that on an institutional plane, the subject is 'dehumanised', and a systemic approach is followed.

Object refers to the goal of the activity, that is, what the activity is directed towards (Engeström & Sannino, 2010). In other words, the *object* acts as a channel to guide individual actions and make connections through the collective activity. Engeström described the o*bject* as an oval space aiming to indicate the potential within activity systems for a field space characterised by movement, possible contradiction, tension, and potential for changes. In this study, the goal of the activity was to develop student teachers' pedagogical knowledge and skills to contextualise mathematics by infusing ethnomathematics.

Rules regulate subject participation within the activity system and provide guidelines for acceptable interactions among the community members (Kain & Wardle, 2011; Leonardo & Manning, 2017). In other words, they regulate the individuals' actions towards the goal and relations with other members in the activity. In addition, rules describe the historical and cultural norms, expectations, conventions, and social relations that implicitly and explicitly regulate the interaction between entities and the activity and interactions within the system. In this study, teacher educators and student teachers as subjects of activity systems were guided by various rules.

Community refers to individuals in an activity system who share the object and are guided by the rules (Havenga, 2019). In other words, it describes the social contexts in which the activity takes place and the participants who share the experiences. These participants in the activity system might either support or prevent the 'object' from being achieved in the activity system (Mentz & De Beer, 2019). Thus, community plays an essential role in promoting interactions between the participants towards achieving the goals of the activity system. In this study, the community consisted of teacher educators, facilitators and student teachers.

Division of labour refers to how tasks are distributed within the community, that is, what is being done by individuals to achieve the goal of the activity (Foot, 2001). It facilitates the identification of roles, responsibilities and tasks and is consistently being negotiated based upon the positions of power within the community. Leonardo and Manning (2017) underscored that in the community there exists a division of labour in which each subject or subjects have particular actions or tasks to be perform on the activity. In this study, the division of labour focused on the role of both teacher educators and student teachers in the activity systems.

Outcome describes the results of the subjects' interaction with the objects, tools, community, rules, and division of labour of the activity system (Hsu et al., 2010). The outcomes of an activity can be the intended ones, but there can also be others that are unintended.

CHAT application has gained prominence in the integration of IKS pedagogies in the education context (Mentz & De Beer, 2017, 2019; Petersen et al., 2019; Potgieter, 2019; Sebotsa, 2020; White et al., 2019). CHAT has often been used as a theoretical and analytical tool to design or redesign teachers' professional development interventions. In this regard, CHAT can be used as a research lens to identify what barriers exist in implementing inquiry learning in order to equip teachers to prepare learners for the 21st century (De Beer & Ramnarain, 2012). However, CHAT can also be used to look at reasons why teachers use transmission mode teaching practices. Thus, the professional development interventions could guide teachers on how to structure their classrooms such that they develop learners' skills required in the 21st century.

CHAT has also been found effective in providing researchers with opportunities to address the problems that could be identified within the activity system (Mentz & Josef de Beer, 2019). A focus on the professional development interventions could be revisited with the intention to redesign to ensure effective realisation in the teaching and learning environment. I find this relevant in the context of my study in that I did not only seek to investigate how student teachers are prepared or not on ethnomathematical perspectives during their pre-service teacher education programmes, but also wanted to scaffold their professional development through an ethnomathematics intervention workshop. Thus, CHAT could provide insight into the guidelines distilled from the data. The intention was to equip them with ethnomathematics knowledge and skills they could transfer into their prospective classrooms.

3.3.2 Contradictions and tensions within CHAT

Within an activity system, there are internal tensions, or contradictions, that build up over time and can hinder or promote the activity system towards its intended outcome (Amory, 2010; Engeström, 1987; Foot, 2014; Gretschel et al., 2015). According to Hamen Farrar (2016), when tensions are brought about consciously, they can lead to a change in one or more of the elements within an activity system, which eventually transforms the whole system. Furthermore, Foot (2014) contended that they are lenses through which participants in an activity can reflect on the developmental trajectory of the activity system and understand its dynamics. In other words, contradictions open views to create opportunities for innovations and new ways of performing the activity. Transformation of the activity system cannot take place until contradictions are identified and acted upon.

Engeström (1987) identified and described four contradictions that could arise within an activity system, namely: a) primary contradictions which are internal, occurring within each and any of the nodes of the activity system; b) secondary: between two or more modes, constituents; c) tertiary: between a newly established mode of activity and remnants of the previous mode of the activity, difference in motive or motive; and d) quaternary which are external, between the newly reorganised activity and its neighbouring activity system, central and peripheral activities.

The application of the contradictions as tools for analysis brings clarity to the complex system and allows the researcher to visualise the gaps that may be present internally with nodes or externally with other systems. Engeström (2001) highlighted that the contradictions act as a research guide and transformation of the activity system occurs when they are resolved. A key aspect of contradictions is that their recognition delivers insight into the change and development possibilities of activities. Building upon the notion of contradictions, the current study examined potential contradictions that were represented within pre-service mathematics teacher education for possible transformative processes towards the development of student teachers' ethnomathematical perspectives as pedagogies for teaching mathematics. According to Foot (2014), contradictions should not be perceived as problems or deficit within the activity system in which they occur. The suggestion is that contradictions cannot be removed as they form an integral part towards transformation of an activity system.

3.4 CONCEPTUAL FRAMEWORKS

In this section I focus on the following intermediate theories: embodied, situated and distributed cognition; self-directed learning; pedagogical content knowledge; and mathematics knowledge for teaching.

3.4.1 Embodied, Situated and Distributed Cognition

In this study, I adopted the ESDC perspective to argue the affordances of ethnomathematics in pre-service mathematics teachers' education. The socio-cultural contexts within ESDC provide justification for the use of ethnomathematics approaches in contextualising mathematics. Ramnarain (2008) pointed out that successful learning is based on "recognising the social context of learning and the effect of the learners' socio-cultural background" (p. 6). The contention is that learning cannot be viewed as an isolated process (Hardy-Vallée & Payette 2008; Maxwell & Chahine, 2013), as it is linked to social activities (De Beer & Petersen, 2016). In the same vein, Anderson (2007) pointed out that learning as a cognitive process is dependent on the active interactions with the socio-environmental contexts.

Furthermore, the relevance of ESDC in this research study is the notion that different modalities such as bodily movements and cultural artefacts play an essential role towards learners' understanding mathematics concepts (Chahine, 2016; Speight Vaughn & De Beer, 2020, Wilson, 2002). In particular, Chahine (2013) underscored that "bodily movement, use of cultural artifacts, acts of drawing pictorial displays, verbal language as well as use of written symbols … play [a role] in understanding mathematical concepts" (p. 4). Similarly, various researchers agree that physical activities (situated cognition) are considered as an extension of the brain as it controls all the bodily activities (embodied cognition) (Brits et al., 2016; Chahine 2013; De Beer & Petersen, 2016; De Beer & Van Wyk, 2019; Hardy-Vallée & Payette, 2008; Holvikivi, 2007). The contention is that the student teachers should be seen and understood in the context of their sociocultural background and environment. When student teachers engage in ethnomathematics practices such as Morabaraba, they use their hands (body), as an extension of their brain to draw the Morabaraba board and identify numerous mathematical shapes. This could help them to establish the link between mathematics and ethnomathematics.

In addition, ethnomathematics practices provide practical ways through which the role of different modalities could be realised towards mathematical understanding and developing mathematics skills. For example, when student teachers get involved in the physical activity through playing indigenous games, it could strengthen their synaptic connections in the brain which results in understanding mathematics concepts. Thus, ESDC is essential in ethnomathematics as it offers an opportunity to look at how student teachers rely on cultural artefacts to develop and express their mathematics knowledge.

Basically, the ESDC notion connects ethnomathematics to mathematics, thus making it relevant for my study on the affordances of ethnomathematics integration in pre-service teacher education. To reiterate, when student teacher experiences learning from ethnomathematics epistemologies, it also helps them to seek ways through which they can integrate ethnomathematics in their prospective classrooms. A focus on ethnomathematics in pre-service teacher education will equip student teachers with ways they can utilise learners' sociocultural contexts. Chahine (2016) affirmed that ethnomathematics is rich, providing many ways in which to learn mathematics, and when such ways are shared with other members in their community, knowledge become distributed. Thus, if students are equipped with ethnomathematics epistemologies, they will probably distribute such knowledge in their classroom communities.

3.4.2 Self-directed Learning

Self-directed learning (SDL hereafter) is defined as "a process by which individuals take the initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating outcomes" (Knowles, 1975, p. 19). It is rooted in the belief that learners should be able to learn to decide "what, how, where and when" to learn on their own (O'Shea, 2003, p. 63). According to Manning (2007), Knowles's conceptualisation of self-directed learning is underpinned by five key assumptions, namely:

> the human being grows in capacity and needs to be self-directing as an essential component in maturing; learners' experiences become an increasingly rich resource for learning that should be exploited along with the resources of experts; individuals become ready to learn what is required to perform their evolving life task or to cope more adequately with their life problems; the natural orientation of individuals is task or problem-centered; learners are motivated by internal incentives such as the need for self-esteem. (p. 108)

Self-directed learning is an essential skill required in a 21st century characterised by a changing educational landscape, which demands student teachers to be empowered with pedagogies to promote learner-centred approaches in their prospective classrooms. According to Mentz and De Beer (2019), to transform South Africa's education system, where teachers depend on teacher-centred approaches, it is essential to prepare student teachers with regard to new innovative strategies. From Machaba and Dhlamini's (2021) point of view, innovative indigenous pedagogy such as ethnomathematics acknowledges and values learners' independent learning with minimal guidance by the teachers, which demonstrates attributes of self-directed learning (De Beer & Mentz, 2016, 2019). The contention is that self-directed learners have the desire for growth, hence in this study I sought to empower student teachers' growth on ethnomathematical perspectives during the ethnomathematics intervention workshop. As indicated earlier, ethnomathematics as an empowering teaching approach can be used for the enhancement of SDL skills for student teachers' personal growth and professional development. Thus, when student teachers are exposed to ethnomathematics, they can become self-directed learners who will find relevant ways they can contextualise mathematics through ethnomathematics in their prospective mathematics classrooms.

In Knowles's (1975) view, self-directed learning could be enhanced through the assistance of others. This implies that being a self-directed individual does not necessarily suggest learning on your own (Pemberton & Cooker, 2012). In the context of my study, this assistance of others was viewed from Vygotsky's scaffolding, as discussed previously, within ZPTD. Ideally, self-directed learning can be enhanced through scaffolded instructions during an ethnomathematics intervention workshop. While self-directed learning focuses on the student teachers taking responsibility for their own learning, it does not necessarily exclude the role of the teacher educators or other facilitators in the learning process (Benson, 2011; Thornton, 2010). Hence, to reiterate, the ethnomathematics intervention workshop facilitators modelled practical ways through which ethnomathematics can be integrated to contextualise CAPS mathematics concepts; thus, promoting a pathway for student teachers' independence in their prospective classrooms.

Furthermore, self-directed learners are able to find or develop relevant resources that they can use to achieve their goals (Havenga, 2017, Jackson, 2019; Knowles, 1975; Van der Walt, 2014). From ethnomathematical perspectives, cultural resources such as indigenous games and art in buildings can serve as essential teaching tools. It is my contention that a focus on the affordances of ethnomathematics will prepare them to use relevant resources based on learners' cultural contexts. Student teachers will likely want to learn more about learners' cultural contexts, which can be utilised to create effective learning environments in their prospective classrooms, thus showing characteristics of self-directed learning.

3.4.3 Pedagogical Content Knowledge

According to Shulman (1987), pedagogical content knowledge (PCK hereafter) is "the amalgam of content and pedagogy that is the province of educators" (p. 8). Shulman (1986) underscored that PCK can be understood as "the ways of representing and formulating the subject making it comprehensible to others" (p. 9). Mishra and Koehler (2006) held the same view as Shulman (1986) that PCK "is concerned with representations and formulations of concepts, pedagogical techniques, and knowledge of what makes concepts difficult or easy to learn" (p.1027). These views on PCK suggest that it helps teachers to apply pedagogical strategies to make content meaningful to the learners (Chikiwa, 2017; Gess-Newsome, 2015; Marshman & Porter, 2013). In Nilsson and Karlsson's (2019) view, "PCK has become a way of understanding the complex relationship between different knowledge components and how these are integrated within the use of specific teaching approaches" (p. 421). Thus, PCK is rooted on the premise that knowledge of a subject is as important as the knowledge of teaching strategies (discussed in 2.4) required to facilitate learners' access to mathematics knowledge.

According to Shulman (1986), PCK can be characterised by three components: Subject matter content knowledge, PCK, and curricular knowledge. Firstly, subject matter content knowledge can be understood as teachers' in-depth understanding about the subject. According to Barnes (2007), it consists of the substantive knowledge and the syntactic knowledge. On the one hand, substantive knowledge refers to methods in which ideas, procedures, principles, and theories are presented in a mathematics content. On the other hand, syntactic knowledge refers to the application of mathematics processes such as reasoning, conjecture, proofs, and theorems to establish the "truth or falsehood" and "validity or invalidity" (Shulman, 1986). Both these knowledge domains are necessary for teachers' PCK development.

Secondly, PCK can be understood as the knowledge of pedagogical approaches that teachers can use in their classrooms to teach mathematics meaningfully (Chikiwa, 2017). According to Woolfolk (2010), PCK is the teachers' use of pedagogical knowledge and skills to enhance learners' understanding of abstract concepts. Lastly, knowledge of the curriculum can be understood as teachers' knowledge about the curriculum aims and principles underpinning a specific subject. Teachers' knowledge of the curriculum is important as it guides them in what should be taught across various phases of schooling. For the purposes of this study, these components are discussed in the next section through the lens of mathematics knowledge for teaching as conceptualised by Ball et al. (2008).

3.4.4 Mathematics Knowledge for Teaching

As a result of Shulman's conceptualisation of PCK, various researchers (e.g., Ball et al., 2008; Hawkins, 2012) focused on the subject-specific PCK frameworks. One such framework relevant to the current research is Mathematics Knowledge for Teaching (MKT hereafter) developed by Ball et al. (2008) and is particularly useful in teaching mathematics. According to Ball et al. (2008), MKT can be understood as "the mathematical knowledge needed to carry out the work of teaching mathematics" (p. 395). In this regard, it can be argued that it is essential for pre-service teacher education training to develop student teachers' MKT to teach mathematics effectively in their prospective mathematics classrooms. MKT will provide student teachers with an in-depth knowledge and comprehension on what mathematics is and what pedagogies they can use in the teaching processes. Hence, Ball et al. (2008) highlighted that mathematical knowledge is an essential requirement in the teaching and learning of mathematics.

Ball et al. (2008) identified two interrelated domains as key features of MKT framework. These are subject matter knowledge (SMK hereafter) and PCK, as shown in Figure 3-6 below. Although I discuss the SMK domain, it is in the latter domain that the affordances of ethnomathematics find its relevance.

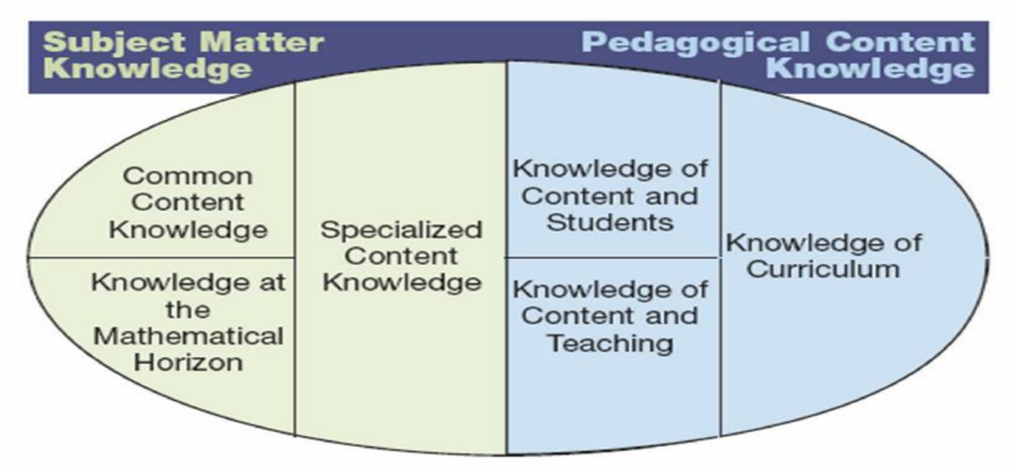


Figure 3-6: Mathematics Knowledge for Teaching.

(Source: Ball et al., 2008, p. 377)

3.4.4.1 Subject Matter Knowledge domain

SMK refers to the amount of organisation of knowledge in the teachers' minds about the discipline (Ball et al., 2008; Lee et al., 2018). From Hawkins's (2012) point of view, it is characterised by mathematical knowledge and understanding concepts and principles and the ways in which they are developed. Similarly, it includes "multiple representations of mathematical concepts and procedures; ways to reason mathematically, solve problems, and communicate mathematics effectively at different levels of formality" (NCTM, 1991, p. 132). In other words, student teachers should be trained to master mathematics, to have nuanced understanding about its facts, principles, axioms and all the theorems related to school mathematics and beyond in order for them to be able to teach their prospective learners. Thus, student teachers have to grasp subject mathematics knowledge in order to cultivate learners' conceptual understanding in mathematics.

In the MKT framework, SMK is characterised by three domains: Common Content Knowledge (CCK hereafter), Horizon Content Knowledge (HCK hereafter), and Specialised Content Knowledge (SCK hereafter). Firstly, CCK refers to mathematical knowledge and skill used in general settings; settings not necessarily unique to teaching. It is applicable in various professions (business, statistics) that use mathematics. In other words, this knowledge relates to the mathematics content knowledge that can be applied in everyday living, regardless of age and profession (Chikiwa, 2017). While CCK is not considered as an essential component of teaching, researchers such as Ball et al. (2008) and Nolan et al., (2015) recommended that teachers should understand the mathematics they teach and be able to identify learners' errors and misconceptions during problem solving.

Secondly, HCK can be understood as “the knowledge the mathematics teacher has of the total span of mathematics in and beyond the curriculum (in a certain phase)” (Potgieter, 2020, p. 24). It helps teachers to have a nuanced understanding of mathematics concepts and the connection that exists between them. This suggests that HCK focuses on the interrelated relationship across mathematics knowledge areas in the curriculum. In Jakobsen et al.’s (2013) view, teachers need to be able to teach mathematics in a way that supports learners to comprehend the connection between mathematics topics.

Lastly, SCK refers to mathematical knowledge and skills relevant to teaching (Ball et al., 2008). It is the knowledge specifically required for purposes of teaching mathematics. This suggests that teachers must have a distinctive mathematical knowledge, understanding, and reasoning in order to teach mathematics (Wilkie, 2016).

3.4.4.2 Pedagogical Content Knowledge domain

Relevant to this study, is the PCK domain; PCK consists of knowledge of content and students (KCS), knowledge of content and teaching (KCT), and knowledge of content and curriculum (KCC). These constructs are discussed below.

Firstly, KCS refers to knowledge that integrates knowing about students and about mathematics (Nolan et al., 2015). It “implies an understanding of students’ thinking and what makes the learning of particular concepts easy or difficult but does not include knowledge of teaching moves” (Ball et al., 2008 p. 378). KCS enables teachers to anticipate what learners may find challenging during resolution of mathematics activities. Wilkie (2016) and Park et al. (2011) pointed out that teachers’ KCS contributes towards knowing how learners develop knowledge and common mistakes they can commit in learning mathematics. This suggests that teachers should also be able to identify and enunciate learners’ misconceptions as they work on mathematics activities.

Secondly, KCT refers to a combination of knowing about teaching and about mathematics (Ball et al., 2008). Similarly, Wilkie (2016) noted that KCT includes knowledge about how to choose appropriate representations and examples to build on learners’ understanding during their learning endeavours. Research has shown that learners’ prior knowledge and experiences are essential to enable them to establish a connection between ideas. Learners’ experiences, shaped by their social, cultural backgrounds, contribute to their prior knowledge, which is necessary in the learning environment. Thus, student teachers should be trained to build on their prospective learners’ understanding though relevant representations from learners’ cultural experiences. According to Furuto (2014) and Shirley and Pedro Palhares (2016), learners’ cultural knowledge and experiences play an essential role in their learning process. It is therefore necessary for student teachers to be able to draw examples from learners' social and cultural experiences to promote effective learning in their prospective classrooms.

Lastly, KCC refers to the knowledge of the content requirements of the curriculum and materials that can be used to teach certain topics (Ball et al., 2008; Kılıç, 2011). The implication of KCC is that student teachers should be equipped with knowledge of the mathematics curriculum. Basically, student teachers should be trained to meet the requirements of the CAPS curriculum and its specific aims. According to SADBE (2011), one of the specific aims of the mathematics curriculum points out that

> Mathematical modeling is an important focal point of the curriculum. Real life problems should be incorporated into all sections whenever appropriate. Examples used should be realistic and not contrived. Contextual problems should include issues relating to health, social, economic, cultural, scientific, political and environmental issues whenever possible. (p. 8)

What can be inferred from the specific aim of the curriculum is that it proposes that student teachers should be able to contextualise mathematics by integrating materials from learners' social, cultural, and environmental backgrounds in their prospective mathematics classrooms. Thus, if this aim is to be realised, student teachers need to be equipped with knowledge and skills to utilise learners' cultural backgrounds in the teaching and learning of mathematics. With this specific aim in mind, this research study sought to explore the affordances of ethnomathematics in pre-service teacher education programmes and expose student teachers, through the ethnomathematics intervention workshop, to practical ways of integrating learners' cultural backgrounds. It is when student teachers are able to contextualise mathematics by integrating ethnomathematics in their prospective classrooms that they will "show Mathematics as a human creation" (SADBE, 2011, p. 8), which is another specific aim articulated in the CAPS mathematics policy document.

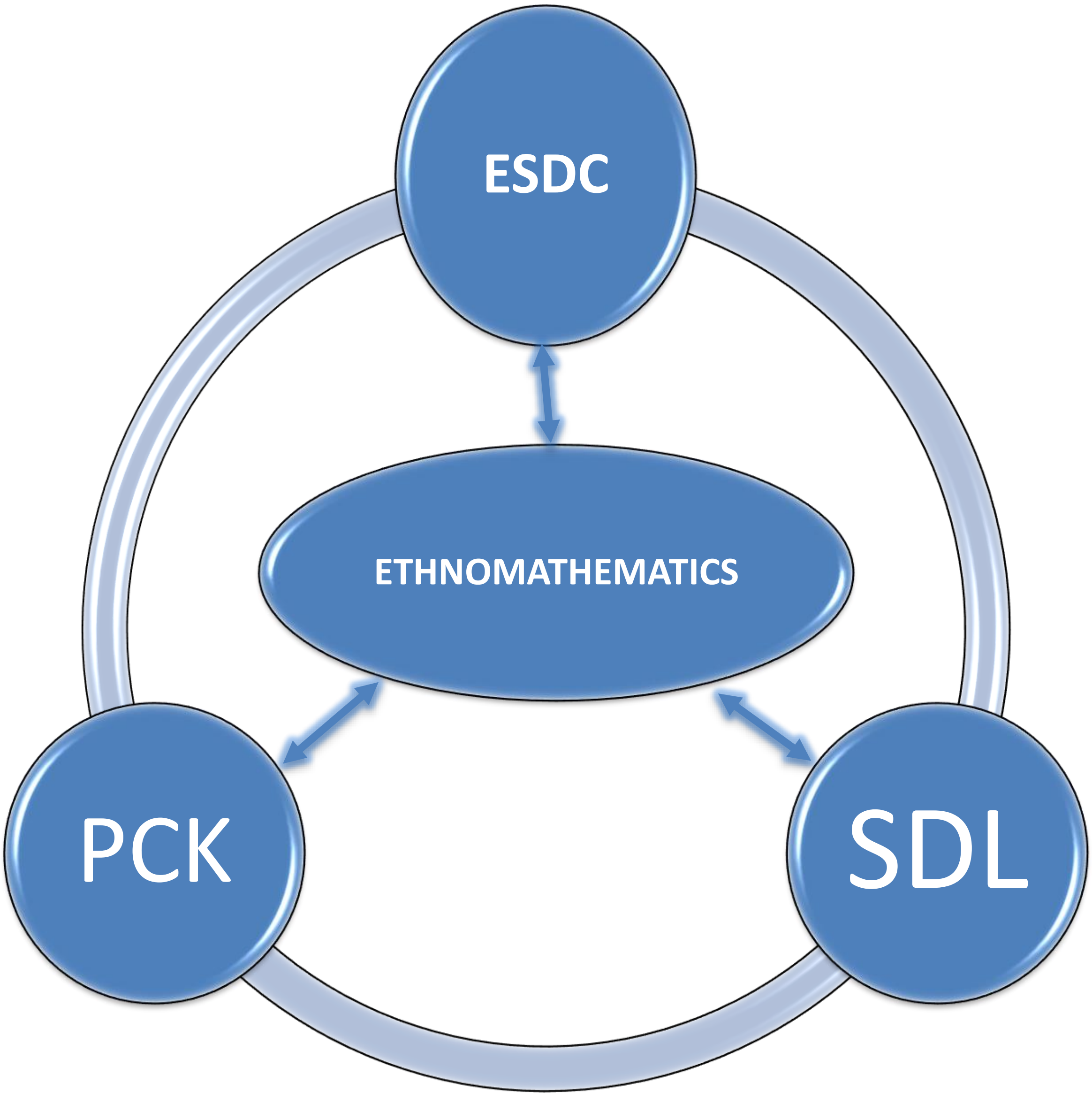


Figure 3-7: The relationship between ethnomathematics and each of the constructs as utilised in this study

3.5 CHAPTER SUMMARY

The third chapter outlined the theoretical and conceptual frameworks. On the one hand, the rationale for sociocultural theory, in particular, Warford's (2011) ZPTD, was justified as a theoretical framework underpinning this research study. Furthermore, CHAT was also discussed as a versatile research lens. On the other hand, various intermediate theories and how they give relevance to a focus on ethnomathematics was also elaborated. In the following chapter, I will explain how the study was conducted by describing the research methodology.

CHAPTER 1

- BACKGROUND AND CONTEXT OF THE STUDY

CHAPTER 2

- LITERATURE REVIEW

CHAPTER 3

- THEORETICAL AND CONCEPTUAL FRAMEWORKS

CHAPTER 4

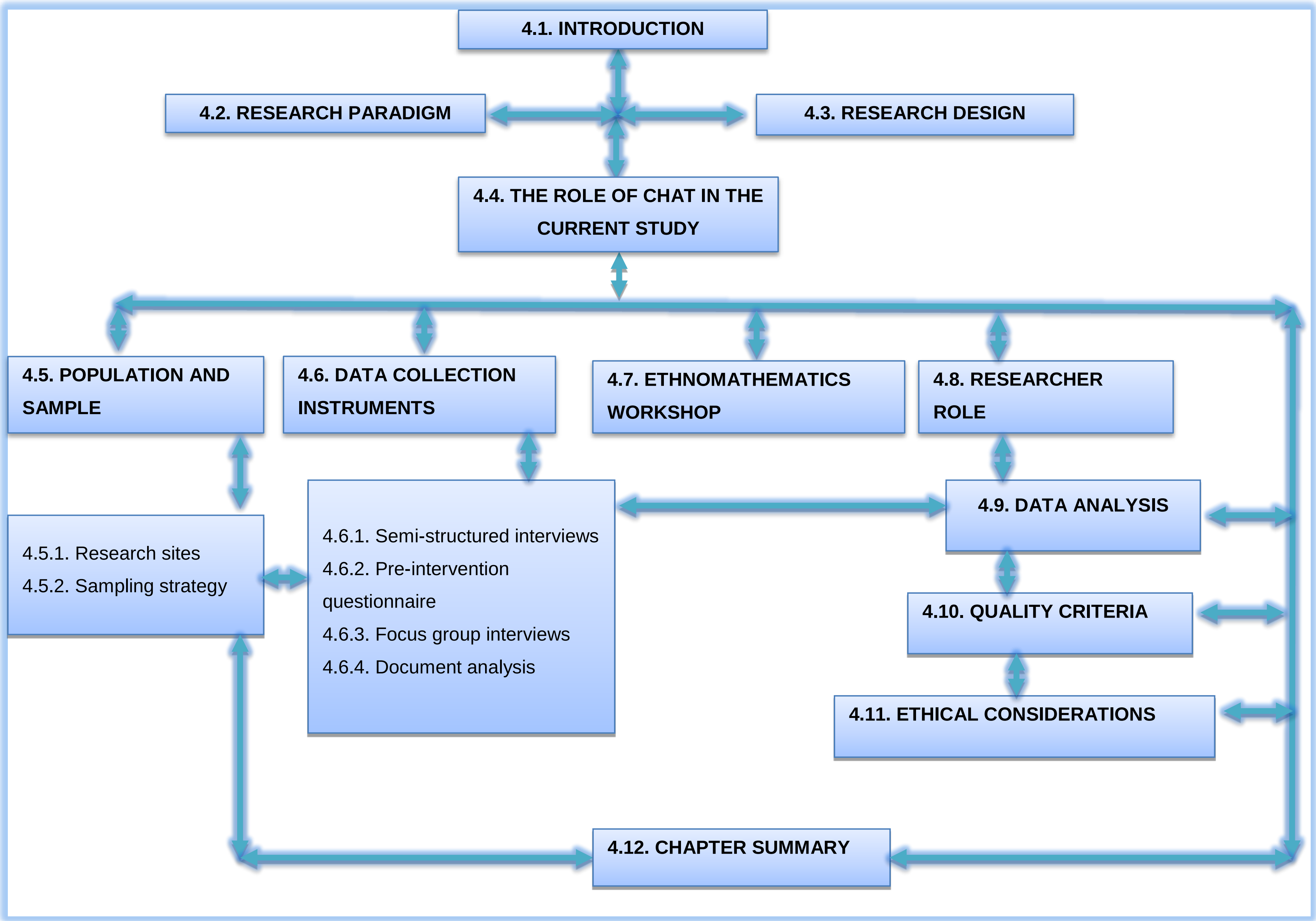
- RESEARCH DESIGN AND RESEARCH METHODOLOGY

CHAPTER 5

- PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

CHAPTER 6

- SUMMARY OF THE MAIN FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION


4.1. INTRODUCTION
4.2. RESEARCH PARADIGM
4.3. RESEARCH DESIGN
4.4. THE ROLE OF CHAT IN THE CURRENT STUDY
4.5. POPULATION AND SAMPLE
4.6. DATA COLLECTION INSTRUMENTS
4.7. ETHNOMATHEMATICS WORKSHOP
4.8. RESEARCHER ROLE
4.5.1. Research sites
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4.6.1. Semi-structured interviews
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4.6.4. Document analysis
4.9. DATA ANALYSIS
4.10. QUALITY CRITERIA
4.11. ETHICAL CONSIDERATIONS
4.12. CHAPTER SUMMARY

CHAPTER 4

RESEARCH DESIGN AND RESEARCH METHODOLOGY

4.1 INTRODUCTION

The previous chapter focused on the theoretical and conceptual frameworks related to the current study. In this chapter, the research methods and steps taken in describing the affordances of ethnomathematics perspectives in pre-service teacher education programmes are described. Firstly, this section describes the research paradigm which framed the study, Secondly, I discuss the research design which this study followed. Then, I provide justification for the role of CHAT as used in the study. Thereafter, the population and sample strategy employed are explained, before the data collection instruments employed. I then provide an account of the ethnomathematics workshop which took place at one of the selected universities. This is followed by outlining my role as the researcher and elaborating on how data were analysed. This is followed by quality criteria I ensured for the study's trustworthiness. Thereafter, ethical considerations which were uphold are discussed. Finally, I provide a summary of the aspects which underpinned this section.

4.2 RESEARCH PARADIGM

Kuhn (1962) first described a paradigm as a philosophical way of thinking. According to Guba and Lincoln (1994), a paradigm explains researchers' fundamental worldviews which provide guidance for research. As a worldview, it is underpinned by postulations and principles, ideals that are central towards understanding and explaining reality (Cohen et al., 2007; Denzin & Lincoln, 2018; Mabotja, 2017). The idea the paradigm is useful in understanding and describing the ultimate reasons that govern the nature of reality. According to Cohen et al., (2018), a theoretical paradigm is essential for conceptualisation of the overall viewpoint from which the research is designed and carried out. As a result, I considered it essential to frame this study within a worldview which would provide holistic insight and guidance towards investigating ethnomathematical perspectives in pre-service mathematics teacher education.

Both quantitative and qualitative researchers are guided by various research paradigms in conducting research. From a philosophical perspective, paradigms embrace combined systems of beliefs based on *ontology* (i.e., view of the nature of reality); *epistemology* (i.e., the relationship between the knower and the known); *methodology* (i.e., a disciplined approach to generating that knowledge); and *axiology* (the values and beliefs that we hold) (Cohen et al., 2000, 2018;

Creswell, 2014; Kivunja & Kuyini, 2017). According to Edelheim (2014), these four philosophical elements

> lay the foundations for how we, as individuals, understand the world we live in, the determinations we make about issues relating to truth, and the matters we consider to be of value to us individually, and to society at large. (pp. 30-31)

In addition, they are related in that the choice of ontological viewpoint guides researchers' epistemological viewpoint. Similarly, the epistemological viewpoint also guides researchers' choice of methodology (Krauss, 2005; Mabotja, 2017). This further suggests that both ontology and epistemology are central in choosing the relevant methodology for research.

Four conventional types of research paradigms are often implemented in conducting research: positivism, post-positivism, critical theory and interpretivism. For clarity, only interpretivism is referred to in this research study. The interpretivist paradigm ontological standpoint is rooted in the belief that reality is "socially constructed, complex and ever changing" (Thomas, 2003, p. 6). It implies that interpretivism rejects the single objective view of reality and advances that individuals interpret and create their own meanings based on experiences and perceptions. In the context of this study, I considered interactions with teacher educators, the ethnomathematics expert and student teachers as essential to understanding the ethnomathematics phenomenon in their pre-service mathematics teacher education. The construction of meanings is primarily situated within social interactions with the teacher educators, an ethnomathematics expert and student teachers at selected universities as natural settings.

The interpretivism epistemology relies on "the specific contexts in which people live and work in order to understand" (Creswell, 2013, p. 25) participants' meanings and experience. In this regard, the aim of the research depended on the teacher educators', ethnomathematics expert's and student teachers' views about ethnomathematics—the phenomenon under the investigation. This provided a rationale for the research study; the participants are teacher educators, the ethnomathematics expert and student teachers, and therefore accommodate multiple views about ethnomathematical perspectives in pre-service mathematics teacher education at selected universities.

Furthermore, the interpretivist paradigm methodological element focuses on methods that will stimulate in-depth understanding of the phenomena under investigation in its unique context (Cohen et al., 2018; Kivunja & Kuyini, 2017; Mack, 2010; Tuli, 2010). This research study used open-ended questions to interview the participants to share their views about their world to gain an in-depth understanding of the phenomenon. In this research study, I relied upon the teacher educators' and student teachers' "views of the situation being studied and [recognised] the impact on the research of their own background and experiences" (Creswell, 2003, p. 8). Thus, I did not address transferability to satisfy the external validity that positivists often seek to establish (refer to section 4.10 for quality criteria). The results of this study were unique to the context of pre-service mathematics teacher education at selected universities. In addition, the interpretivist paradigm allows the researcher to obtain personal contact with the teacher educators, an ethnomathematics expert, and student teachers. This resulted in my 'deeper understanding' of ethnomathematical perspectives in pre-service mathematics teacher education.

Moreover, the interpretivist axiological standpoint is grounded upon principles and meanings in conducting research, and the ethics considerations guiding the researcher (Cohen et al., 2018; Kivunja & Kuyini, 2017). Herein, it is important for researchers to adhere to ethical guidelines, ethics committees and institutional research code of conduct which provide guidance for what researchers can do and not to do. Thus, amongst others, axiology in interpretivist paradigm help researchers to protect participants from any harm that could arise as a result of their participation in the study. Detailed account of ethical considerations in provided in Chapter 4, section 4.11.

4.3 RESEARCH DESIGN

A research design is generally defined as the logic or master plan adopted to answer research questions in a valid way. This master plan describes the selection of participants and the research methodology adopted by the researcher to answer research questions (Cohen et al., 2007). The main aim of a research design is to ensure that the data gathered provide researchers with opportunities to address the research problem logically and sufficiently (Cohen et al., 2018). There are generally six traditional research designs which qualitative researchers choose from (e.g., action research, case study, ethnographic, grounded theory, historical and phenomenology) (Cohen et al., 2018; Creswell, 2013). For clarity and precision, only the case study (multiple case study) will be described in the current study. The type of multiple case study used in this study is an instrumental multiple case study. An instrumental multiple case study focuses on examining particular cases in order to gain insight into an issue, phenomenon or a theory (Creswell, 2013; Cohen et al., 2018; Merriam & Tisdell, 2016). In this study, ethnomathematics is viewed as a phenomenon because I sought to gain insight into how it is integrated in pre-service mathematics education programmes. Thus, the current study adopted an instrumental multiple instrumental case study design to provide an in-depth understanding of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa.

By employing the instrumental multiple case study, the current study aimed to produce a rich and holistic account of an ethnomathematical perspective in pre-service teacher education. As stated by Creswell (2013), “in a collective case study (or multiple case study), the one issue or concern is again selected, but the inquirer selects multiple case studies to illustrate the issue.” (p. 99). The multiple instrumental case study was used not so much with the aim of comparing pre-service mathematics teacher education at selected universities, instead with the intention of interpreting and relating them to each other in order to draw attention to the ethnomathematical perspectives in pre-service mathematics teacher education. Thus, multiple cases with no separate discussion of each case but an overall cross-case analysis was adopted in data presentation and analysis (Yin, 2009). I intended therefore to understand how ethnomathematical perspectives are integrated in pre-service mathematics teacher education at selected universities in South Africa.

In addition, the instrumental multiple case study was found to be relevant as the current study’s conceptualisation was based on the principle of eliciting participants’ views about ethnomathematical perspectives in pre-service mathematics teacher education at their universities. Cohen et al. (2007) explained that an essential feature of a case study is that it “portray, analyse and interpret the uniqueness of real individuals and situations through accessible accounts” (p. 85). Consequently, it would have been difficult if not impossible to answer research questions using experimental designs in this present study. Thus, a case study as an interpretivist design, allows the researcher to explore participants’ thought processes and perceptions that may be difficult to extract using surveys or experimental designs. In this regard, the current study adopted a case study to explore teacher educators’, an ethnomathematics expert’s, and student teachers’ perceptions and understanding of ethnomathematical perspectives in pre-service mathematics teacher education.

4.4 THE ROLE OF CHAT IN THE CURRENT STUDY

Mentz and De Beer (2017) and Rogoff (1995) elaborated that CHAT can be applied on three planes, namely, the personal, the interpersonal, and the institutional or community plane. Firstly, CHAT as conventionally used on a personal plane. It focuses on the system of interpersonal engagements and arrangements that are involved in participation in activities (by promoting some sort of involvement and restricting others), which is managed collaboratively by individuals and their social partners in face-to-face or other interactions, as well as in the adjustment of arrangements for each other’s and their own activities (Rogoff, 1995). In other words, the focus could be on teacher professional development where the teacher is regarded as the subject of the activity system. Secondly, on an interpersonal plane level, the focus is on the interaction between various stakeholders (e.g., the teacher educator, and the student teacher) engaging in a collaborative activity (Mentz & De Beer, 2017). Thus, in this case, the focus could be on the teacher educator as a subject in one activity system and the student teacher as a subject of the other activity system. Lastly, on the institutional plane, the subject of the activity system is considered as an institution or the system instead of a person (Mentz & De Beer, 2017).

As a result, in this study I juxtaposed two activity systems (namely the teaching activities of the teacher educators, and the learning activities of the student teachers) as a unit of analysis (Mentz & De Beer, 2017). In other words, the teacher educator is the subject in one, and the student teacher the subject in the other, as shown in Figure 4-1. Thus, CHAT provided the framework for describing the integration of ethnomathematical perspectives in pre-service mathematics teacher education, and as a lens to illustrate the "barometers of tensions" as often referred to by Mentz and De Beer (2017, p. 98). As a result, CHAT enabled representations and influences on how ethnomathematics is integrated in pre-service mathematics teacher education. CHAT was used in this study on the interpersonal plane to analyse how teacher educators foster student teachers' ethnomathematical perspectives in teacher education programmes. Thus, I used CHAT in the study to explore affordances of ethnomathematical perspectives in pre-service mathematics teacher education.

To take the analysis a step further, I also used CHAT on the institutional plane where student-teacher professional development on ethnomathematics was considered as the activity system. I relied on this institutional plane analysis to conceptualise the guidelines for student teacher professional development on ethnomathematics pedagogical knowledge and skills as illustrated in Chapter 6.

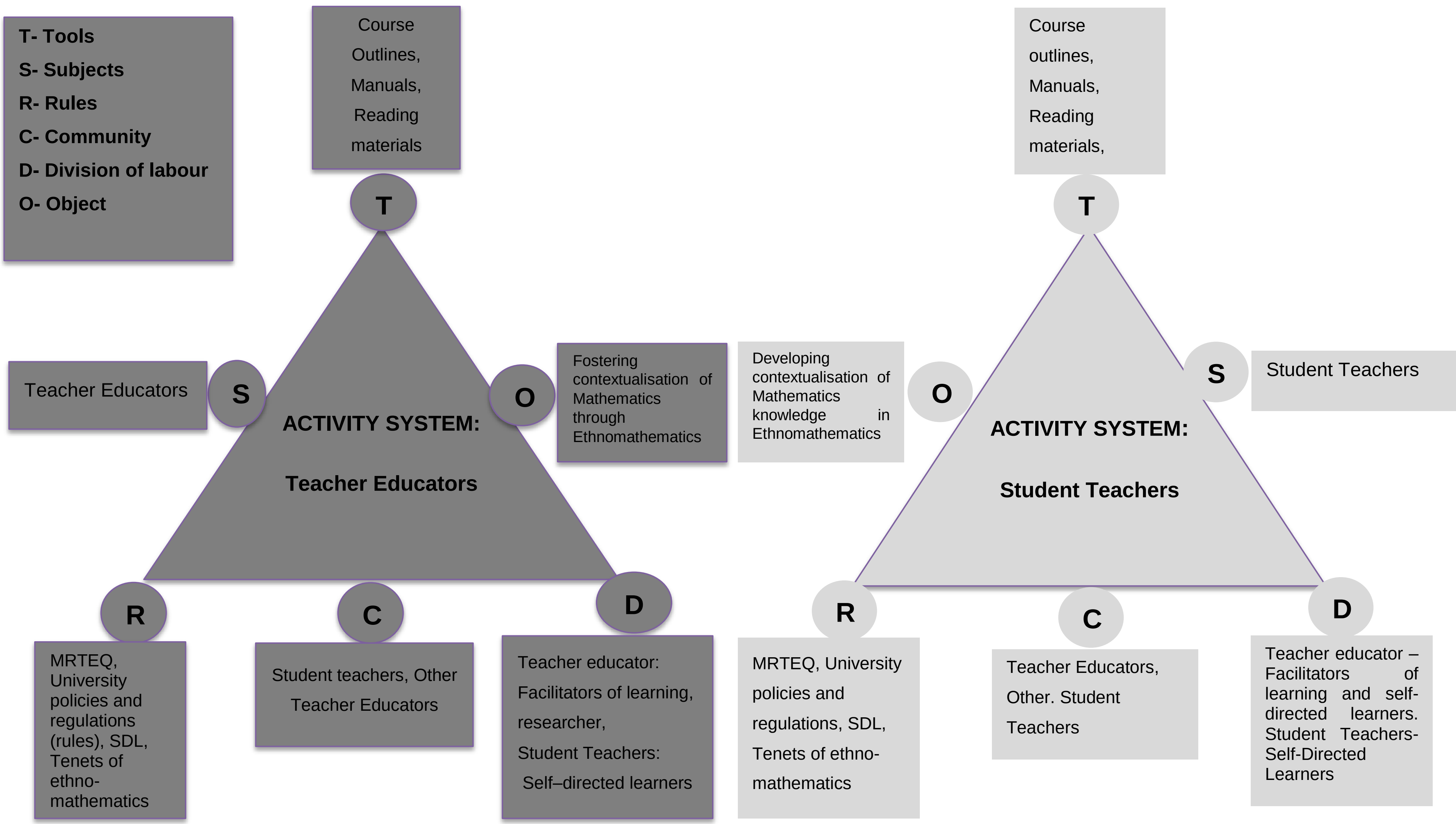

Figure 4-1: CHAT applicable to this study

4.5 POPULATION AND SAMPLE

4.5.1 Research sites

4.5.1.1 University A

University A is one of the four universities in Limpopo Province. It is historically a black university. Currently, like all the other universities and irrespective of their history, they are open to students of all races. However, University A still caters predominantly for black students. The students are mainly from the Venda, Tsonga, and Sepedi cultural groups. These cultural groups are classified as largely rural and are rich in indigenous practices such indigenous buildings and games. In addition, University A comprises four faculties, including Humanities, which houses the School of Education that offers, amongst others, undergraduate and postgraduate Mathematics teacher education programmes. The participants from University A were four mathematics education student teachers and three teacher educators. The number of student teachers from University A does not represent the total number of student teachers who are registered at University A but student teachers who agreed to participate in the Study.

4.5.1.2 University B

University B is a merger of a historically white university and historically black university located in North West Province. On one hand, the historically black university catered for predominantly black students from rural communities. On the other hand, the historically white university served predominantly white Afrikaans students with Christian backgrounds. Since the merger in 2002, the university is open to all. In addition, University B consists of three academic campuses. However, this study focused only on one campus. University B consists of eight faculties including Education, which offers pre-service mathematics teacher education. Three mathematics education student teachers, two teacher educators and the ethnomathematics expert were participants from University B. As with University A, the number of student teachers from University B does not represent the total number of student teachers who are registered at University B but student teachers who agreed to participate in the Study.

4.5.1.3 University C

University C is one of the two post-democratic public universities in South Africa. It is located in the Northern Cape, and open to all races. University C is composed of four academic schools including the School of Education, which houses the Department of Natural Sciences Teaching where the participants in the study came from. From University C, ten mathematics education student teachers and one teacher educator participated in the study. The number of student teachers from University C does not represent the total number of student teachers who are registered at University C but student teachers who agreed to participate in the Study.

4.5.2 Sampling strategy

The current study, as opposed to experimental research that adopts random sampling, adopted purposive sampling. Purposeful sampling is "based on the assumption that the investigator wants to discover, understand, and gain insight and therefore must select a sample from which the most can be learned" (Merriam, 1998, p. 61). In other words, the researcher selects participants and sites that can purposefully inform an understanding of the research problem and central phenomenon in the study (Creswell, 2013). Prior to data collection, I planned to sample 12 teacher educators (four from each university), two ethnomathematics experts and 30 student teachers (10 from each university) as participants for this research study. However, this plan was negatively affected by COVID-19 and related restrictions. For example, face-to-face learning was suspended to curb the spread of COVID-19, which resulted in online learning. The implication was that the majority of students were learning from home and as a result I could not reach the initial proposed number of 46 participants. As a result, 17 student teachers (University A, n=4; University B, n=3; University C, n=10), one ethnomathematics expert and six teacher educators (University A, n=3; University B, n=2; University C, n=1) from the selected universities in South Africa showed interest and participated in the study. As earlier mentioned, 17 student teachers does not represent the total number of student teachers who are registered at the selected universities but student teachers who agreed to participate in the study. These universities were sampled selected on the basis that they offer pre-service mathematics teacher education and are in the researcher's proximity. Thus, the total number of participants in the study (n=24).

As opposed to experimental research designs that use larger sample sizes, the current study focused on a small sample size (Creswell, 2013). In this study, research questions required an in-depth description from each participant, therefore using quantitative designs would not have provided in-depth discussions. Teacher educators were purposively sampled on the basis that they develop and teach mathematics education methodology modules. The ethnomathematics expert participant was sampled on the basis of research publications, postgraduate supervision, and lecturing experience in pre-service mathematics education. Student teachers were selected on the basis that they are enrolled in mathematics education methodology modules.

4.6 DATA COLLECTION INSTRUMENTS

The term collection refers to the means by which data may be collected. These means include observation protocols, interview schedules, and open-ended questionnaires, among others. Table

4-1 summarises the data collection method employed in accordance with research questions. The data-collection instruments described below were used in an attempt to address the primary research and sub-research questions (refer to Chapter 1 – 1.5 - for research questions details).

Table 4-1: Data collection instruments in relation to research questions

Research question and sub-research questions	Data collection instruments			
	Semi-structured Interviews	**Pre-intervention questionnaire**	**Post-intervention Focus Group/Semi-structured Interviews**	**Document Analysis**
	Teacher Educators; Ethnomathematics expert	Student Teachers	Student Teachers	Mathematics education course outlines, Mathematics education course manuals, Ethnomathematics artefacts
What are the affordances of a focus on ethnomathematical perspectives in mathematics teacher education programmes?				
What are the teacher educators', expert's and student teachers' understanding and perceptions about ethnomathematical perspectives?	X	X	X	
How does the pre-service mathematics education curriculum prepare student teachers for ethnomathematical perspectives?	X	X	X	X
What are the challenges that both teacher educators and student teachers could face in the incorporation of ethnomathematical perspectives in the mathematics curriculum?	X	X	X	
What are the guidelines for the effective incorporation of ethnomathematical perspectives in pre-service mathematics teacher education?	X	X	X	x

4.6.1 Semi-structured interviews

Interviews are commonly employed as an essential qualitative data collection tool (Cohen et al., 2007, 2018; Creswell, 2013; McMillan & Schumacher, 2014; Yin, 2009). Creswell (2013) defined an interview as a two-way conversation in which the interviewer asks the participant questions to collect data and to learn about the ideas, beliefs, views, opinions, and behaviours of the participant. This method of data collection considers the centrality of human interaction for knowledge production and emphasises the social situatedness of research data. Cohen et al. (2007) stated that "Interviews enable participants—be they interviewers or interviewees—to discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view" (p. 349). Similarly, Creswell (2013) maintained that the primary purpose of the interview is to see the world through the eyes of the participant. In other words, interviews offer qualitative researchers the opportunity to understand participants' meanings and experiences in their social contexts about certain issues of interest.

According to Creswell (2014), three types of qualitative research interview formats are distinguished: structured, semi-structured, and unstructured interviews. Firstly, a structured interview is characterised by a set of predetermined questions with no scope for follow-up questions to participants' responses that require further clarification or explanation. Secondly, a semi-structured interview, which is relevant in this study consists of a set of key questions that allows the researcher or participants to diverge to pursue a response in detail. In this study, the semi-structured interview schedules consisted of open-ended questions derived from the main research question and sub-research questions which guided the research study. In addition, some of the questions were informed by literature. During the semi-structured interviews, I did not ask a set of questions in a predetermined order. Lastly, unstructured interview, which is not relevant in this study do not have a set pattern and questions are not arranged in advance (Cohen et al., 2018).

In this study, seven semi-structured interviews were conducted between 2019-2021 academic years with teacher educators, the ethnomathematics expert and student teachers in the form of face-to-face (2), telephonic (4), and electronic interview formats with the aim of obtaining an in-depth understanding of ethnomathematics in pre-service mathematics teacher education at three selected universities in South Africa. As a result of the COVID-19 pandemic, I could not visit all the universities, hence other forms of semi-structured interview were considered. During the face-to-face and telephonic interviews, I used open-ended questions to consider prompts and probes, as recommended by Creswell (2010). Through prompts, I was able to ask the participants to extend, elaborate, add to, provide detail for, clarify, or qualify their responses, thereby addressing richness, depth of response, comprehensiveness, and honesty that are some of the hallmarks of successful interviewing (Cohen et al., 2018; McMillan & Schumacher, 2014). In this regard, open-ended questions guided the interviews; however, the exact sequence and wording did not have to be followed with each respondent (Cohen et al., 2009). Furthermore, open-ended questions allowed teacher educators to freely respond by explaining and justifying their responses based on their knowledge and experiences without being limited.

Interviews with the teacher educators and the ethnomathematics expert were arranged to take place in their offices (face-to-face) and telephonically at a time convenient to them, as earlier indicated. Interview sessions were between 35 and 60 minutes. The interviews were recorded with the permission of the teacher educators, and the recorded clips were saved and verbatimly transcribed. The interview responses were arranged into themes, which are presented and interpreted in the next chapter.

Although other forms of semi-structured interviews such as electronic submissions provide little opportunities to prompt the participants, I asked them to respond to the questions to the best of their knowledge and experiences. Thus, the student teacher and teacher educators who submitted electronically were asked to provide detailed information about their views on ethnomathematical perspectives in pre-service mathematics teacher education.

4.6.2 Qualitative pre-intervention questionnaire

A qualitative open-ended questionnaire was used prior to the workshop (University C) to explore the student teachers' understanding and preparedness to incorporate ethnomathematics pedagogies in their prospective mathematics classrooms. The pre-intervention questionnaire consisted of ten open-ended questions derived from the main research question and sub-research questions which guided the research study. In addition, the questionnaire adopted some of the items from Cronje (2015, p. 117). According to Johnson and Christensen (2012), questionnaires provide self-reported data about the participants' insights and views on a variety of issues under investigation. Thus, it was considered necessary first to establish student teachers' prior experiences, knowledge, and preconceived ideas about ethnomathematics pedagogies through using a pre-intervention/workshop questionnaire. Although, 10 student teachers participated in the workshop, only seven pre-intervention questionnaires were completed and returned within the first 45 minutes of the workshop. Three student teachers attended the workshop late and their responses would have been influenced by the activities they participated in and, as a result, they were not given a questionnaire.

4.6.3 Focus group interviews

Chambliss and Schutt (2012) defined a focus group as a group comprised of individuals with certain characteristics, who are brought together by a researcher to discuss a given issue or topic. This method of data collection is characterised by group discussions which are guided by a researcher in order to broaden and diversify the range of responses on a particular research topic. It is in these group discussions that the data emerge. In the view of Cohen et al. (2018), focus group interviews offer participants the opportunity to discuss with each other rather than with the researcher, such that the views of the participants can emerge.

In this study, focus group interviews were conducted with the mathematics education student teachers at two of the selected universities between 2020-2021 academic years. The focus group interview schedules consisted of semi-structured topics, where question order was relative to importance of issues in the research agenda (Cohen et al., 2018). The purpose of the focus group interviews was to allow student teachers to talk about their perceptions on ethnomathematical perspectives and how teacher education programmes prepare them to use these pedagogical tools. As a result of the COVID-19 pandemic and lockdown restrictions, I could not visit the universities to reach the initial proposed number of focus groups. In total, two focus group sessions were conducted at University A and University C. However, personal arrangements were made with various student teachers (from University B) to complete and submit their responses electronically (one student teacher) and others (two student teachers) opted for a telephonic interview, as earlier mentioned. This offered me an opportunity to obtain their views related to the phenomenon under investigation in the study.

In University A, the focus group was conducted in a postgraduate lab which was accessible and free from distractions (Cohen et al., 2018; Creswell, 2013). The focus group in University A, which took place in 2020 academic year consisted of four student teachers' participants and was 50 minutes long, while the focus group in University B was replaced by electronic correspondence with the participants. Although the optimal size for a focus group is six to eight participants, a focus group can work successfully with as few as three and as many as 14 participants (Gill et al., 2008).

At University C, the focus group was conducted in a lecture hall where the workshop was held during 2021 academic year. The focus group interview lasted for about 1 hour 40 minutes. Although 10 student teachers participated in a workshop, the focus group consisted of eight student teachers; two student teachers had to leave at the end of workshop due to other assessment-related activities.

4.6.4 Document Analysis

Document analysis refers to “a systematic procedure for reviewing or evaluating documents—both printed and electronic” (Bowen, 2009, p. 27). This method can be used by researchers to elicit meaning related to the phenomenon under investigation (Cohen et al., 2018; Merriam & Tisdell, 2016). Since the study aimed to produce detailed descriptions of ethnomathematical perspectives in pre-service mathematics teacher education, document analysis was necessary. Document analysis in educational institutions may take the form of official documents, personal documents, and artefacts. As a result, the following documents, where applicable, were gathered from each university:

- Mathematics education course outlines
- Mathematics education course manuals
- Faculty or school of education calendar

These documents were examined, analysed, and interpreted to elicit meaning, gain understanding, and develop empirical knowledge (Merriam & Tisdell, 2016) regarding ethnomathematical perspectives at selected universities in South Africa. These documents served as a data source to obtain information, especially related to policy, with respect to ethnomathematical perspectives in pre-service mathematics teacher education. In these documents, I sought to examine concepts based on learners’ everyday contexts, culture and mathematics, teaching mathematics in contexts, among others, which are linked to ethnomathematics. Furthermore, document analysis in the study was also used in combination with semi-structured interviews and focus groups as a means of data triangulation.

4.7 ETHNOMATHEMATICS INTERVENTION WORKSHOP

The Tshimologo Shoestring Kit (Van der Walt, 2015-2020)

Van der Walt participated in three funded projects lead by Prof J. de Beer at NWU:

(i) Funded by the National Research Foundation (NRF): The affordances of Indigenous Knowledge for Self-Directed Learning;

(ii) Funded by the National Research Foundation (NRF): STEM teachers: learning from Indigenous Knowledge Systems Practitioners (2015-2020); and

(iii) Funded by the Fuchs Foundation: Teachers without borders' creating Indigenous Knowledge, Science Labs in Rural schools: Developing the Tshimologo Mathematics shoestring kit (2016 – 2020).

Prof Van der Walt designed and developed the Tshimologo Shoestring Mathematics Kit during the above-mentioned projects. The TSMK was developed as part of the Short Learning Programme in Ethnomathematics. In this study, during the Ethnomathematics intervention workshop at university C, participants were introduced to the Tshimologo Mathematics Shoestring Kit (TSMK) and each one received examples of the content of the TSMK (Tshimologo means "a new beginning").

The ethnomathematics workshop was compiled, designed, and presented by both the promoter and co-promoter (Van der Walt & De Beer, 2021). This workshop focused on the affordances of ethnomathematics in the school [mathematics] curriculum (the content of the TSMK). The aim was the professional development of student teachers in the use of ethnomathematics in pre-service mathematics teacher education at University C by introducing them to the content of the TSMK. It was developed from the key elements of Design-Based Research (DBR). Thus, the intervention sought to provide "solutions for complex problems" such as student teachers' lack of ethnomathematics pedagogies "in education practices" (Plomp & Nieveen, 2010, p. 13), particularly in pre-service mathematics teacher education programmes. The workshop was based on Warford's (2011) ZPTD to scaffold student teachers' professional development. Thus, the focus of the ethnomathematics workshop was on equipping student teachers with the necessary pedagogical knowledge and skills to contextualise mathematics, and also to provide ethnomathematics resources they can use in their prospective mathematics classrooms. Thus, the workshop focused on scaffolding student teachers' professional development towards incorporating ethnomathematics in their prospective mathematics classrooms. The participants in the workshop were a group of 10 mathematics education student teachers from intermediate, senior phase, and FET teacher education programmes at University C.

In the research study, the 1-day workshop consisted of four stages as shown in Table 4-2 below: Pre-intervention questionnaire, presentations of ethnomathematics, ethnomathematics-based activities, and final discussions and focus groups.

Table 4-2: Ethnomathematics 1-day intervention workshop at University C

Stage	Phase
1. Pre-intervention questionnaire	Student teachers complete the pre-intervention open-ended questionnaire.

2. Ethnomathematics and its role in mathematics education	Presentation of ethnomathematics definitions and discussions on its role in mathematics education.
3. Ethnomathematics activities (TSMK)	Multiplication in many cultures' activities.
	Morabaraba game activities.
	Boomwhackers, music and fractions activities.
	De Bono Thinking hats activities
4. Final discussions and focus group interviews	Discussions about ethnomathematics' epistemological implications.

Some of the ethnomathematics resources (TSMK, Van der Walt, 2015-2020) used and made available to student teachers are shown below:

Figure 4-2: Some of the ethnomathematics resources (TSMK) used during the ethnomathematics workshop (Van der Walt, 2015-2020)

4.7.1 Stage 1: Introduction and pre-intervention questionnaire

In this stage, participants were welcomed, and the purpose of the workshop was discussed. The facilitators of the workshop were also introduced. Furthermore, the student teachers were given a pre-intervention questionnaire (Addendum E:11) to explore their experiences and understanding of mathematics found in sociocultural contexts or everyday lives.

4.7.2 Stage 2: Presentation on ethnomathematics

The presentation on ethnomathematics focused on reading and discussion of ethnomathematics. In this stage, student teachers were exposed to the literature on ethnomathematics, its evolution and rationale in mathematics education by the facilitators. Sources that were consulted included, amongst others, the works of Ubiratan D'Ambrosio.

4.7.3 Stage 3: Ethnomathematics-based activities

Stage 3 consisted of ethnomathematics-based activities, namely, multiplication in many cultures, the Morabaraba indigenous game and 2-D geometry, and music, fractions and boomwhackers (Van der Walt, TMSK) and De Bono's thinking hats (Presenter: Prof J. De Beer).

4.7.3.1 Multiplication in many cultures

Firstly, multiplication in many cultures focused on how various cultures performed multiplication. For example, modern world multiplication, Egyptian multiplication, Chinese multiplication, and the area model techniques were explored. The focus of these activities was to introduce student teachers to how various cultural groups carry out multiplication. The student teachers engaged in different activities on multiplication in many cultures, as shown in the photographs below.

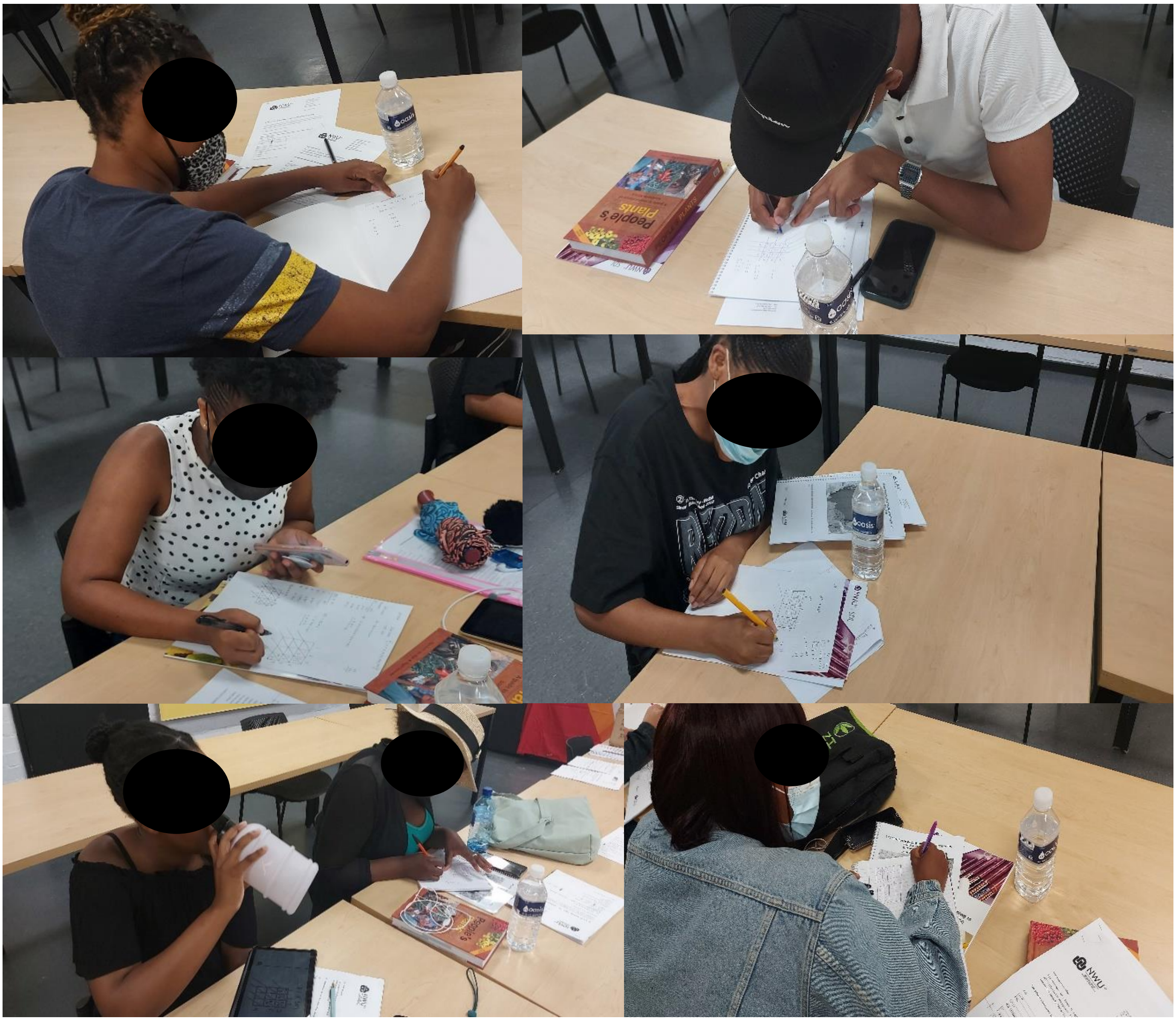

Figure 4-3: Student teachers engaging in activities involving multiplication in many cultures

4.7.3.2 Morabaraba indigenous game and 2-D Geometry concepts

Morabaraba indigenous game activities focused on exploring how various CAPS mathematics topics such as 2D shapes, reflection, and rotations can be taught using the game. The facilitators explained and demonstrated how geometry concepts can be taught using the game from neuro-science perspectives and embodied, distributed and situated cognition. In addition, the student teachers engaged in Morabaraba activities which, amongst others, included playing the Morabaraba game, and a demonstration of geometry concepts, as shown in the photographs below.

Figure 4-4: Facilitator explaining and demonstrating geometry concepts

Figure 4-5: Student teachers playing Morabaraba game

Figure 4-6: Student teachers exploring 2-D geometry shapes using the Morabaraba gameboard (TMSK)

Figure 4-7: The facilitator engaging with student teachers during the Morabaraba game

4.7.3.3 Music, boomwhackers, and common fractions activities

Music, boomwhackers, and common fraction activities focused on exploring the teaching and learning of common fractions using music and boomwhackers. Boomwhackers are defined as "coloured plastic tubes, accurately cut into specific lengths to produce different tones when hit against a surface (table, hand or floor) and work like xylophones" (Van der Walt et al., 2019, p. 201). In these activities, western musical symbols (notes) were transposed to common fractions. The student teachers practised the rhythms of the songs such as the National Anthem of South Africa (Nkosi Sikelel'i Africa) by clapping their hands in accordance with the facilitator's guidance and the length of the note. Thereafter, each student teacher was given boomwhackers of different colours and those with similar colours came together (or stood next to each other) and struck boomwhackers according to the colour-coded fractions on the music-fraction poster (Figure 4-8). Thus, the colour of the fraction represented the colour of the boomwhackers to be used and the common fraction indicated the length of the note played with the boomwhackers. In this instance, the facilitator pointed to a specific fraction from the music-fraction poster, read the fraction out loud while student teachers struck their different boomwhackers for the length of the fraction time. When student teachers struck their specific boomwhackers at a specific time, as pointed out by the facilitator, a song was created. These activities were used as a practical interactive way of exposing student teachers to ethnomathematics and how it can be integrated to contextualise CAPS mathematics concepts such as fractions.

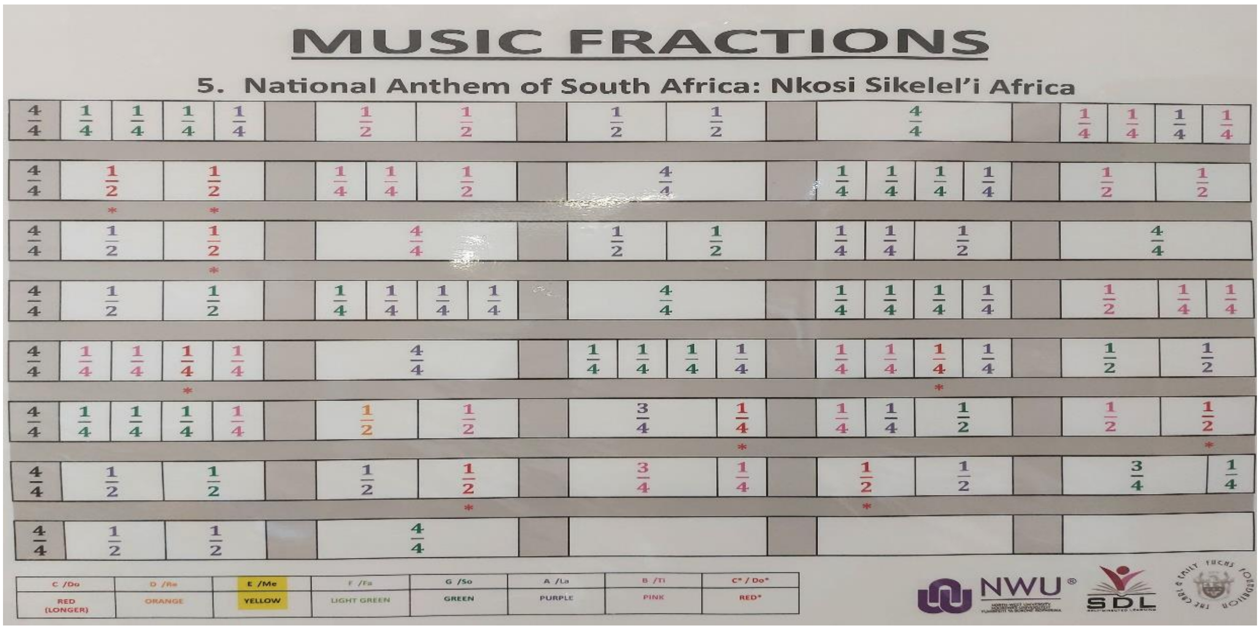

Figure 4-8: Music-fraction poster for Nkosi Sikelel'i Africa (Van der Walt, @TMSK, 2015-2020)

Photographs showing the music, boomwhackers, and common fractions activities are shown in Figure 4-9.

Figure 4-9: Facilitators and student teachers during music, common fractions and boomwhackers activities (TMSK)

4.7.3.4 De Bono’s thinking hats activities

The De Bono’s thinking hats (De Bono, 1985) activities focused on collaborative learning where student teachers worked together. The integration of ethnomathematics in the mathematics classrooms is still quite new. As a result, teaching through ethnomathematics is characterised by diverse perspectives. In this session, student teachers were exposed to De Bono’s thinking hats and applied the strategy to discuss their diverse views. Their discussion was based on the discussion question ‘Is there a place for ethnomathematics in the classroom?’ posed by the facilitator. Student teachers worked in groups of three. Each group chose two hats to focus their discussion. In addition, student teachers were allocated 20 minutes for deliberation and presentations as shown in the photographs below (Figures 4-10 and 4-11). The contention was that ethnomathematics approach could be viewed from different viewpoints.

Figure 4-10: Student teachers engaging on De Bono’s thinking hats discussion question

Figure 4-11: Some of the student teachers presenting their viewpoints on the De Bono's thinking hats discussion question

4.7.4 Stage 4: Final discussions and post-intervention focus group interviews

In this stage, the focus was on student teachers' reflections and their experiences based on the ethnomathematics workshop. Student teachers were given opportunities to articulate their views and conceptions about ethnomathematics.

4.8 RESEARCHER'S ROLE

The researcher's role in qualitative research is mainly to gather research data (Creswell, 2011). As a result, my role in the study was to conduct focus group interviews and semi-structured interviews with the student teachers and teacher educators, respectively. Thus, engaging with the student teachers and teacher educators who were the main participants in the study. These offered me opportunities to collect data relevant to addressing the research questions as presented in the context and background in Chapter 1. I was therefore guided by the pre-prepared semi-structured and focus group interviews to ask questions relevant to the study.

Qualitative research is often limited by researchers' sensibility and integrity (Merriam, 2009). As a result, it is imperative as a researcher that I am guided by ethical considerations while conducting research. Accordingly, I was guided by ethical considerations such as confidentiality and protection of participants, as discussed later in this chapter.

4.9 DATA ANALYSIS

Once the data have been collected, the researcher needs to make sense of the data by beginning the process of data analysis (Merriam, 2014). Creswell (2014) described data analysis as an attempt to organise data systematically and to provide explicit details of what the case is and to explain why the case evolved in a specific way.

The data analysis process followed the following steps, as outlined by Renner and Taylor-Powell (2003):

- Step 1—get to know your data;
- Step 2—focus the analysis;
- Step 3—categorise information;
- Step 4—identify patterns and connections within and between categories.

Step 1 entailed getting to know the data. I listened to and transcribed *verbatim* the audiotapes for the focus group interviews and individual interviews to get a general sense of the data.

Furthermore, transcribed data were read and read over again in order to familiarise and make sense out of the data.

Step 2 involved the focus of the analysis. The focus of data analysis in the current study was on research questions. In other words, data were organised by research questions guiding the study to look across all participants and their responses in order to ascertain consistencies and differences.

Step 3 focused on data categorisation. Pre-set categories entail starting with a list of themes or categories before you categorise the data and search for text that matches the themes (Renner & Taylor-Powell, 2003). The categories in this study were derived from the research questions. In other words, essential statements and phrases relating to the research questions were extracted from the data generated. This provided direction for what to look for in the data.

Step 4—entails identifying patterns and connections within and between categories. As earlier mentioned, the present multiple case study does not seek to present each case separately, but an overall cross-case analysis is adopted in data presentation and analysis (Yin, 2009).

4.10 QUALITY CRITERIA

Quality criteria assists researchers to ensure trustworthiness of the findings. Furthermore, quality criteria play an essential role in demonstrating that there has been rigour in carrying out the research. The current study was provided some rigour through confirmability, credibility, transferability, and dependability. These constructs are discussed below.

4.10.1 Confirmability

According to Lincoln and Guba (1985), confirmability focuses on the researcher's ability to demonstrate that the data and interpretation of the findings represent the participant's responses and not the figments of the researcher's imagination. Among the plausible explanations for confirmability is that the claims made about the data should be traceable to their sources. I achieved confirmability by providing rich quotes from the participants in the interpretations and discussions section, as shown in the following chapter. In the current study, original tape recordings of teacher educators, ethnomathematics expert, and student teachers as well as copies of documents have been kept for use in the event that an audit of the claims that were made in the study are needed later.

4.10.2 Credibility

Credibility refers to the extent to which the inquiry has been conducted in such a manner as to ensure that the subject has been accurately identified and described (Schurink et al., 2011). This implies the truth of the data or the participants' views and their interpretation of such data or views by the researcher. In this study, member checking was done through convening a focus group with the student teachers and interviews with teacher educators to give them an opportunity to view the raw data and comment on the accuracy to confirm the credibility of the information and narrative account (Shenton, 2004). In addition, the current study employed multiple data collecting methods such semi-structured interviews, focus group interviews, and document analysis to achieve credibility, as recommended by Merriam and Tisdell (2016).

4.10.3 Transferability

According to Merriam and Tisdell (2016), transferability is concerned with the extent to which the findings of one study can be applied to other similar contexts. This implies that the transferability will be adequate in a study if the researcher provides the reader with descriptions that detail the context in which the study took place. As indicated earlier in this chapter, the rich and extensive set of details concerning the methodology and research setting provides features of universities from which generalisations may be made to a collection of diversified pre-service mathematics teacher education with similar characteristics to the one in the study.

4.10.4 Dependability

Dependability refers to the extent to which the researcher employs techniques to show that if the work was repeated in the same context, with the same methods and the same participants, similar results would be obtained (Shenton, 2004, p. 67). In this present study, more than one type of data collection was used to support or contradict the interpretations that were made (Merriam & Tisdell, 2016). The pre-intervention questionnaire and focus group interviews with student teachers were conducted to complement the semi-structured interviews with teacher educators and the ethnomathematics expert which, when used on their own, could have been prone to bias from my subjective interpretations of situations (Creswell, 2013).

4.11 ETHICAL CONSIDERATIONS

Ethical issues are important to educational researchers who intend to conduct any form of research that involves human beings as their participants (Creswell, 2013). In order to conduct this study, ethical clearance (NWU-00792-18-A2) to conduct research at the selected universities was obtained from the Faculty of Education Sciences Ethics at the North-West University, Potchefstroom Campus (Addendum A:1). The permission to conduct the research at selected universities was granted (Addendum B:2-4). It is important to mention here that the names of the universities, acronyms, contact details, and persons included in the permission letters were hidden to protect the identity of the research site, as recommended by Creswell (2011).

In addition, the teacher educators, ethnomathematics expert, and student teachers were provided with an information letter giving a brief background about the study and consent forms (Addendum C:5) detailing their participation, anonymity, and confidentiality before the data collection could begin. The participants completed and returned signed consent forms to show their willingness to participate in the study. Furthermore, the student teachers who participated in the ethnomathematics workshop consented that the photographs taken during the workshop may be published without blurring their faces. I further explained to participants that their participation was voluntary, and they were assured of their right to withdraw from this study at any point without consequences. Moreover, the participants were guaranteed that they would not be exposed to any harmful situation because of their participation in the study (Trochim, 2000).

Furthermore, teacher educators, ethnomathematics expert, and student teachers were assured that pseudonyms would be used to protect their identity. This implies that the participants' real names were not attached to the study. The participants were further assured that the raw data would be kept inside a locked safe for a period of seven years. I also explained to them that raw data would not be accessible to anyone outside the study, except my supervisors.

To ensure ethical issues on documents, Creswell (2003) recommended that permission to use documents be sought from appropriate individuals, in this case teacher educators who developed the mathematics education modules.

4.11.1 Ethical issues in data analysis and interpretation

To ensure ethics in data analysis, I (as mentioned earlier) used pseudonyms to protect the identity of the participants and the research sites. In interpreting data, I provided an accurate account of the data as emerged during data analysis (Creswell, 2003). Participants were also provided with a copy of the research report so they could check the accuracy of the data.

4.11.2 Ethical issues in writing up and disseminating research

In ensuring ethical issues in data reporting, the data were reported honestly without changing or altering the findings to support the research questions (Creswell, 2013). In addition, the research report will be made available for qualified scholars, community members, and professionals, as reports should not remain unpublished (Creswell, 2013).

When publishing the results, I will not submit a thesis that has been previously published or submitted anywhere, as suggested by Creswell (2003). Thus, the thesis will be my original work. In addition, to avoid plagiarism, I have given credit when paraphrasing and quoting scholarly works of other researchers (Creswell, 2003).

4.12 CHAPTER SUMMARY

In this chapter, I focused on methodological issues which underpinned this research study. Amongst other things, I provided the rationale for the interpretivist research paradigm and how it informed multiple case study as a research design. CHAT, as used on the interpersonal and plane, was also explained. Moreover, purposive sampling was justified as a sampling strategy relevant for this study. A focus was also on data collection, and how data were analysed. Furthermore, the ethnomathematics intervention workshop was also discussed. The next chapter focuses on the data presentation, interpretations, and discussions.

CHAPTER 1

- BACKGROUND AND CONTEXT OF THE STUDY

CHAPTER 2

- LITERATURE REVIEW

CHAPTER 3

- THEORETICAL AND CONCEPTUAL FRAMEWORKS

CHAPTER 4

- RESEARCH DESIGN AND RESEARCH METHODOLOGY

CHAPTER 5

- PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

CHAPTER 6

- SUMMARY OF THE MAIN FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION

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5.3. PRESENTATION AND INTERPRETATION OF FINDINGS

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5.5.2 Theme 2: Teacher educators and student teachers perceive ethnomathematics as a relationship between dynamic, evolving cultures and mathematics

5.6. PARTICIPANTS PERCEPTIONS ABOUT ETHNOMATHEMATICS

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5.6.2 Theme 2: Ethnomathematics may develop learners' awareness of the relevance of mathematics in real-life contexts
5.6.3 Theme 3: Ethnomathematics may develop awareness that every culture has contributed to mathematics development

5.7. PREPARATION OF STUDENT TEACHERS ON ETHNOMATHEMATICS IN PRE-SERVICE MATHEMATICS TEACHER EDUCATION

5.7.1 Theme 1: Lack of focus on ethnomathematics in pre-service mathematics teacher education
5.7.2 Theme 2: Integration of diverse cultural techniques, indigenous games, and music to prepare student teachers to contexualise mathematics concepts in learners' everyday contexts
5.7.3 Theme 3: Teacher educators and expert acknowledge the need to prepare student teachers on ethnomathematics towards changing their mindset about the nature of mathematics

5.8. CHALLENGES TOWARDS INTEGRATION OF ETHNOMATHEMATICS

5.8.1 Theme 1: Cultural diversity may hinder integration of ethnomathematics in the classroom
5.8.2 Theme 2: Teacher educators are of the perception that CAPS curriculum is not responsive towards ethnomathematics
5.8.3 Theme 3: Lack of learners' cultural contexts in mathematics textbooks
5.8.4 Theme 4: Lack of ethnomathematics integration and discouragement of student teachers by mentor teachers towards integrating ethnomathematics during work-integrated learning
5.8.5 Theme 5: Technological approaches may hinder integration of ethnomathematics into the teaching and learning of mathematics
5.8.6 Theme 6: The integration of ethnomathematics approaches in the teaching and learning of mathematics is perceived as time-consuming

5.9. CHAT ANALYSIS

5.10. CHAPTER SUMMARY

CHAPTER 5

ETHNOMATHEMATICAL PERSPECTIVES IN PRE-SERVICE MATHEMATICS TEACHER EDUCATION: PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

5.1 INTRODUCTION

The previous chapter described the research design and how data for this study was generated. This chapter presents the results of the current study, which sought to investigate the affordances of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa. Firstly, it describes the data generation process and demographic characteristics of the participants. Secondly, it describes ethnomathematical perspectives in pre-service mathematics education programmes from teacher educators, an ethnomathematics expert (semi-structured interviews), student teachers (pre-intervention questionnaire, focus group interviews) and document analysis (module course outlines, faculty/school of education calendar as well as the mathematics course materials) perspectives. In other words, this chapter offers an interpretive and analytical account of the data that were generated and collected during the study. Finally, it analyses the findings from CHAT perspectives.

5.2 DATA GENERATION PROCESS

Prior to data collection, letters of consent were sent to the three selected universities, teacher educators, an ethnomathematics expert, and student teachers to make the intended research study known in advance, as explained in the methodology chapter. The letters included information about the purpose, information about participating in the study, and a request to access the documents. Furthermore, a request for permission to audiotape the interviews was also detailed in the letters.

The data were mainly collected using semi-structured interviews, a pre-intervention questionnaire, focus group interviews, and document analysis. Both the individual and focus group interviews were semi-structured with open-ended questions to provide the participants with an opportunity to respond spontaneously, and to explore essential issues surrounding ethnomathematics and pre-service mathematics teacher education. I formulated the interview questions guided by the research questions after which they were scrutinised by the supervisors for possible revisions where necessary. Similarly, the pre-intervention questionnaire was also guided by the research, with other questions adopted from Cronje (2015) and Van der Walt (2018).

As was described in the previous chapter, I planned to conduct one-on-one interviews with 12 teacher educators (four from each university), two ethnomathematics experts, and focus groups interviews with 30 student teachers (ten from each university). However, this plan was negatively affected by the COVID-19 pandemic and its related restrictions. As a result, I could not reach the initial proposed number of 46 participants. Three teacher educators and only four male student teachers showed interest and participated in this research study from University A. At University B, only two teacher educators and three student teachers opted for electronic and telephonic interviews. At University C, only one teacher educator showed interest and preferred a telephonic interview and ten student teachers participated in a face-to-face ethnomathematics intervention workshop with eight participating in focus group interviews. In addition, only seven student teachers at University C completed and returned the pre-intervention questionnaire, as explained in the previous chapter.

The names of teacher educators, the ethnomathematics expert, and student teachers who participated in this study have not been revealed, so as to protect their identities. As a result, I am using the following pseudonyms: Teacher Educator A/B/C 1, 2, and 3; Expert (1); and Student Teacher A/B/C 1, 2, 3, etc., where A, B, and C indicate the different universities.

5.3 PRESENTATION AND INTERPRETATION OF THE FINDINGS

In this section, I focus on explaining how results are presented and findings interpreted. The findings are presented in relation to the research questions that guided the study. The data are discussed under four main categories, namely

(1) the participants' demographic characteristics;

(2) the participants' understanding and perceptions about ethnomathematics;

(3) the participants' views on the preparation of student teachers on the use ethnomathematics in pre-service mathematics teacher education; and

(4) challenges that could hinder effective integration of ethnomathematics.

As mentioned earlier, the multiple instrumental case study method was used not so much with the aim of comparing pre-service mathematics teacher education at selected universities, instead in an attempt to interpret and relate them to each other in order to draw attention to the ethnomathematical perspectives in pre-service mathematics teacher education. In total, 14 themes emerged from the data. In each theme, the results from teacher educators, the ethnomathematics expert and student teachers are presented and interpreted separately. However, the synthesis of the findings against literature is done in an integrated manner, particularly in instances where results from both the teacher educators, ethnomathematics expert and student teachers reveal similar findings. Figure 5.1 is a representation of the five main categories and themes used to organise the data.

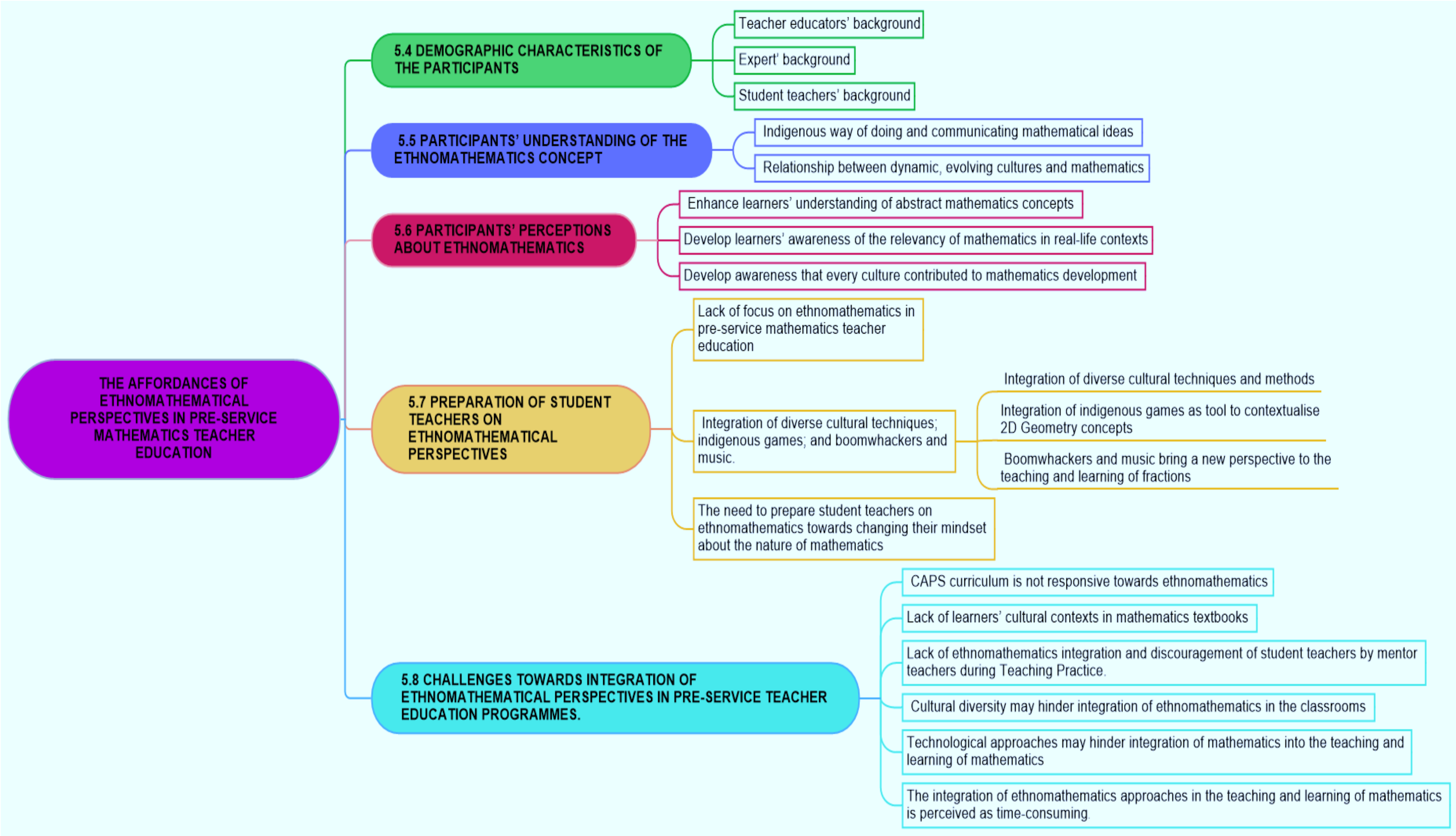


Figure 5-1: A representation of the five main categories used to organise the data

5.4 DEMOGRAPHIC CHARACTERISTICS OF THE PARTICIPANTS

In this section, I provide the participants' demographic information. The demographic information such as race and qualifications could provide a clear reflection of how these characteristics impact the teacher educators to integrate ethnomathematics in pre-service mathematics teacher education. Table 5-1 presents the demographic characteristics of the teacher educators.

Table 5-1: Demographic characteristics of teacher educators

GENDER	Male	3
	Female	3
RACE	African	4
	White	2
QUALIFICATIONS	M.ED	2
	PhD	4
PROGRAMMES	Intermediate Phase	3
	FET and Senior phase	3
LECTURING EXPERIENCES IN YEARS	1-5	1
	5-10	2
	10-35	3
University	University A	3
	University B	2
	University C	1

It can be seen from Table 5-1 that out of the total of six participating teacher educators, three were males and three females. In addition, the participants' race category fell into two categories: African and white. Four teacher educators were Africans and the other two were whites. Both these cultural groups are characterised by unique cultural practices which could play an essential role in contextualising mathematics.

In addition, the participating teacher educators in the research had the highest qualifications, ranging from master's to doctoral degrees. Two teacher educators held master's degrees in Mathematics, while the other four were in possession of doctoral degrees. All the participants were involved in teaching mathematics education modules in pre-service mathematics teacher education programmes. On the one hand, three were involved in intermediate phase (IP) programmes; on the other hand, three were involved in Senior and Further Education and Training (SP&FET) phase programmes. Both the IP and SP&FET are a 4-year bachelor's degree in pre-service mathematics education.

It can also be seen from Table 5-1 that the participating teacher educators in the research had lecturing experience ranging from one year to 35 years in pre-service mathematics education at their respective universities. In this regard, one teacher educator had lecturing experience of between one and five years; two teacher educators between five and ten years, whilst the other three had between 10 and 35 years of lecturing experience. Three teacher educators were from University A; two from University B, whilst the other one was from University C.

Table 5-2: Demographic characteristics of expert participant

Gender		Male
Race		African
Highest Qualification		PhD
Professional Development workshops (Yes/No)		Yes
Subject advisor experience (Yes/No)		Yes
Number of publications	Articles	8
	Conference proceedings	6
	Books/Books Chapter	2
Number of supervised postgraduate students	M	10
	PhD	3
Programme of specialisation: IP/SP/FET		FET
Lecturing experience (in years)		10+

It can be seen from Table 5-2 that the one ethnomathematics expert was an African male with a doctoral degree as the highest qualification. The assumption with regard to African background could be that he had knowledge and experiences of specific cultural practices in his classrooms. He had conducted professional development workshops and served as a mathematics subject advisor in one district. These experiences may have provided him with valuable opportunities to interact with mathematics teachers, learners, curriculum advisors, and other stakeholders in pursuit of alleviating challenges in the teaching and learning of mathematics. It can also be argued that serving as a subject advisor indicated that he might have strong disciplinary, pedagogical, and curriculum knowledge.

In addition, he had a track record of over 16 publications which included eight articles in accredited journals, six papers in conference proceedings and two book chapters. Ten out of 16 publications are related to ethnomathematics field. This indicates that an ethnomathematics expert may be regarded as a research-orientated academic who strives to contribute to ongoing scholarly discourse, particularly in the ethnomathematics field. The results further indicated that the ethnomathematics expert had supervised and produced a total number of ten master's and three doctoral studies. The main focus of these studies was on contextualising mathematics through indigenous knowledge which may show that he had postgraduate supervisory research experience.

Lastly, he had over ten years lecturing experiences in pre-service mathematics teacher education, particularly in Further Education and Training phase. Thus, he has worked with diverse student teachers who aspire to become mathematics teachers.

Next, I will provide and discuss the demographic information regarding the participating student teachers.

Table 5-3: Demographic characteristics of student teachers

Age	**Gender**		**Race**			**Total**	**Specialisation**		**University**		
18-25 years	**Male**	**Female**	**African**	**White**	**Indian**	**17**	**IP**	**FET**	**A**	**B**	**C**
X	6	11	14	2	1	17	10	7	4	3	10

Table 5-3 reveals that 17 student teachers participated in this research study. Of the 17, six student teachers were males and the other eleven were females. In addition, the student teachers' race category fell into three categories: African, white, and Indian. Fourteen student teachers were Africans, two were whites and one was Indian. These diverse cultural backgrounds are rich with diverse cultural practices. In addition, 10 student teachers were enrolled in intermediate phase and the other seven were in FET phase. Four student teachers were from University A; three from University B, whilst the other 10 were from University C. Thus, most of the student teachers who participated in the study were from University C.

5.4.1 Integration of data collection methods and in-text citation

In Table 5-4, I provide a summary of data collection methods linked with the participants and how they are referenced in the analysis and interpretation of the results.

Table 5-4: Integration of data collection instruments and in-text referencing

Participants	Participant number and/or per university	Addendum	Page number(s)	Data collection instrument
Teacher Educator (TE)	A1 / B1 / C1	G	e.g., 1,2	Face-to-face interview (F2F); Electronic submission (ES), Telephonic interviews (TI)
Expert (E)	E1	G	e.g., 1,2	Telephonic interviews (TI)
Student teacher (ST)	A1/B1/C1	H, I	e.g., 1, 2,	Electronic submission (ES), Focus group (FG); Telephonic interviews (TI); Pre-intervention questionnaire (PQ).
Document Analysis (DA)		J	e.g., 1,2,	Module guides.

In Table 5-4, participants' responses linked to the collected data are indicated as TE A2, ES, Add B:6-7, which reads as follows: Teacher Educator, University [A], Number [3], Electronic Submission, Addendum [G], page numbers [6-7]. Similarly, (ST B1, TI, Add H:3) represents student teachers' responses and reads as follows: Student Teacher, University [B], Number [1], Telephonic Interview, Addendum [H], page number(s) [3]. References pertaining to the documentation are read as follows: University [A], Document Analysis [DA], Addendum [Add J]: page number(s) [128].

5.5 PARTICIPANTS' UNDERSTANDING OF THE ETHNOMATHEMATICS CONCEPT

In this section, I focus on the meanings participants attach to the concept of ethnomathematics. In order for teacher educators to develop ethnomathematical perspectives in student teachers, they need to be aware of ethnomathematics concepts. The participant responses indicated diverse understanding of the concept of ethnomathematics. Two themes emerged from the semi-structured interviews: ethnomathematics is defined as:

(1) an indigenous way of doing and communicating mathematical ideas; and

(2) the relationship between dynamic and evolving culture, and school mathematics.

These themes are presented, discussed and interpreted below.

5.5.1 Theme 1: Teacher educators and expert perceive ethnomathematics as an indigenous way of doing and communicating mathematical ideas

The teacher educator and the ethnomathematics expert participants' results from semi-structured interviews expressed ethnomathematics is an indigenous way of doing and communicating mathematical ideas. Mathematics concepts, skills and procedures are strongly linked to how various cultural groups carried out daily activities to meet their daily needs (D'Ambrosio, 1985, 2016). Thus, ethnomathematics finds its roots in the historical, social, and cultural accounts of how different cultural groups apply indigenous techniques to mathematise (Chahine, 2016; Moloi, 2020; Rosa & Orey, 2010). The results revealed that ethnomathematics emphasises that specific cultural groups enact mathematical ideas and skills in their daily living. In this regard, Teacher Educator B2 argued that in the

> *absence of vast communication, in other words, technology and the vast difference distances between cultures, almost each culture developed their own way of doing and presenting, writing diagrams, the concepts and procedures; and it was linked to their context…ethno-mathematics is the way a group of people do and communicate mathematical procedures, describe maths concepts relating to the specific context of their cultures.* (TE B2, ES, Add G:55)

The above quotation from TE B2 illustrates the participant's perception that people from various cultural groups have unique ways of mathematising within their cultural context. Thus, according to TE B2, different cultural groups have, without technological advancement associated with the 21st century, developed methods to present, draw, measure, count, and use other skills in their own cultural contexts. The result indicates that Teacher Educator B2 has an informed understanding that ethnomathematics is based on mathematics concepts and skills situated within cultural contexts and practices. The contention is that daily activities require mathematics procedures and skills in one way or the other. This perception was reiterated by another teacher educator who perceived ethnomathematics as the

> *mathematical practices that is own to my culture, hence indigenous to my people. It is a practice engrained into my peoples' belief system and has influenced their way of doing pertaining to mathematical practices which was passed down from generation to generation, to where it is today*. (TE B1, ES, Add G:47)

Similarly, TE A3 felt that mathematical ideas and skills are connected to cultural practices. In this regard, she explained that ethnomathematics acknowledges that people from various cultural groups "*relied on various indigenous methods to do measurements, counting…. the houses they* *built, art, the beadwork designs and patterns, the indigenous games…have mathematical practices or ideas"* (TE A3, ES, Add G:51). She further explained that these practices found in various cultural contexts demonstrate that *"different cultures had a way of mathematising"* (TE A3, ES, Add G:51). The contention is that cultural practices such as indigenous houses, games, and beadworks, which are dominant in many South Africa cultures, have mathematics in them.

In the same vein, another teacher educator commented that ethnomathematics affirms that: "*mathematics is driven by cultural practices that people in certain places do*" (TE C1, TI, Add G:35).

Furthermore, the expert participant corroborated teacher educators' perceptions that people throughout history, regardless of a lack of formal mathematics taught in schools, were engaged in mathematics activities. In this regard, he argued "*the way they count, they've never gone to school to be in a classroom where they are taught… formal mathematics…were engaged in mathematics* (E 1, TI, Add G:60-61). He further stated various cultural practices: "*[tell] you a story of mathematics.*" The quotations from the expert suggest that mathematics has always been linked with people's everyday lives. Thus, ethnomathematics embrace mathematical ideas found in cultural practices. There are unique mathematical ideas and concepts in sociocultural contexts found outside of the classroom. The contention is that mathematics knowledge can also be developed from sociocultural contexts.

What can be understood from the above four teacher educators and the expert participant's perceptions is that ethnomathematics recognises and affirms that different cultural groups throughout ages have without the aid of technological resources—as are available today—applied mathematical knowledge and skills such as counting, drawing, and measuring in their everyday living and experiences. The findings propose that daily cultural practices and activities found in different cultural groups consist of mathematics concepts and skills and reflect mathematical ideas. The mathematical knowledge and skills reflected in various cultures are understood to be communicated from generation to generation. The traditional houses, games, and other cultural practices from different cultural communities communicate mathematics concepts and procedures, according to the participants. Among the possible explanations for these findings is that ethnomathematics acknowledges that all different cultural groups have developed specific strategies for mathematising. The findings concur with Rosa (2020) who perceived ethnomathematics as diverse ways of knowing and doing mathematics. Researchers such as D'Ambrosio (2016) and Weldeana (2015) pointed out that cultural groups have specific strategies of mathematising, that is, they have developed though culture or cultural practices their own strategies for observing, comparing, classifying, ordering, measuring, quantifying, and inferring.

Hence, ethnomathematics focuses on mathematical ideas found in any cultural group (D'Ambrosio, 1985; Rosa & Orey, 2010).

In the next subsection, I focus on the teacher educators' and student teachers' perceptions of ethnomathematics as the relationship between culture and mathematics.

5.5.2 Theme 2: Teacher educators and student teachers perceive ethnomathematics as a relationship between dynamic, evolving cultures, and mathematics

In this theme, the results from teacher educators, ethnomathematics expert, and student teachers are presented and interpreted. Firstly, I focus on the results from the teacher educators' and ethnomathematics expert's interviews. Secondly, I focus on the results from the student teachers' pre-intervention questionnaire and focus groups. Lastly, I focus on the synthesis of the findings against literature.

(a) Results from teacher educators

The results from the teacher educators' semi-structured interviews revealed that they perceived ethnomathematics as the relationship between dynamic, evolving cultures and mathematics. This view proposes that mathematics can be contextualised within cultures (or cultural ideas and concepts) and then be mathematised in learners' indigenous knowledge for mathematics for better understanding of mathematics. In this regard, TE C1 defined ethnomathematics as the "*relationship that we have between the learning of mathematics and cultural backgrounds that we find mathematics in"* (TE C1, TI, Add G:35). This comment illustrates TE C1's perception that ethnomathematics may not necessarily focus on any cultural backgrounds and practices but those that have mathematics procedures, concepts, and skills.

In line with TE C1's perception, one teacher educator stated that ethnomathematics is a culturally-based teaching approach which "*relies on various cultural backgrounds and artefacts that can be applied in mathematics classrooms. The emphasis is on how culture can be beneficial towards understanding mathematics*" (TE A3, ES, Add G:51). Similarly, TE A2 asserted that ethnomathematics is concerned with mathematics concepts and skills that "*learners can extract from culture"* (TE A2, F2F, Add G:24). These perceptions suggest that ethnomathematics is premised on the application of cultural backgrounds into the teaching and learning of mathematics. Thus, according to the teacher educator participant's perceptions, ethnomathematics seeks to mathematise mathematics concepts through cultural practices.

Similarly, Educator A1 claimed:

> *Ethno…. I suppose it has to do with cultural things. So, ethnomathematics for me will be the relationship between mathematics and culture and seeing how to incorporate culture into the teaching and learning of mathematics or understanding maths or trying to see the mathematics in the cultural structures.* (TE A1, F2F, Add G:16)

This quotation suggests that the teacher educator's perception of ethnomathematics is possibly influenced by the concept of ethno which focuses on cultural aspects.

The above four teacher educator responses show a common (vague) agreement of ethnomathematics as the relationship between mathematics and culture. However, these teacher educators in their perceptions did not explain the exact nature of the relationship they referred to. The contention is that teacher educators perceived that ethnomathematics may be integrated as a teaching strategy that promotes the role of learners' cultural backgrounds in mathematics classrooms.

Although the above teacher educators view ethnomathematics from a cultural perspective, other teacher educators (TE A1; TE C1) raised concerns about the way culture is viewed in defining ethnomathematics. For example, Teacher Educator A1 added that his concern is on

> *defining this culture; we seem to be defining ethnomathematics from culture from traditional sense … and if that's how we look at it then it doesn't incorporate culture as something that is evolving. It's more like we have to go back to something else that has been there and trying to see how to incorporate that in understanding maths*. (TE A1, F2F, Add G:16)

In addition, he further pointed out that,

> *If you take culture as an evolving thing, an evolving phenomenon, everything that you do to provide context will be within culture… I read more on ethnomathematics more often people talk about things that indigenous people have been doing that sort of have maths in it.* (TE A1, F2F, Add G:17)

The above quotations from TE A1 demonstrate the participant's perception that culture within the context of ethnomathematics should not only be limited to cultural historical activities that indigenous people were engaged in, but as a dynamic and evolving concept. The argument is that focusing on culture as a stagnant concept associated with only past cultural practices, could limit the possibilities of learning from the evolving cultural practices, according to Teacher Educator A1. Thus, ethnomathematics should account for past, present and future cultural practices. Learning mathematics only from what indigenous people used to do could result in missing out on valuable contributions of current and future cultural practices.

This goes hand-in-hand with Teacher Educator C1's comment:

> *Culture is dynamic, and it can change anytime…teachers…must be able to move with times and also to understand the cultural context of where they are … Otherwise, they will remain behind and using…context that don't relate to what students are aware of. That will make things very difficult*. (TE C1, TI, Add G:41)

The above assertion from TE C1 further suggests that ethnomathematics should embrace evolving cultural practices that can be used to contextualise mathematics. Thus, each generation has its own unique cultural practices that may be used to teach or learn mathematics concepts. As a result, it is important for teachers to not only be limited to the past cultural practices but also to focus on the current cultural practices relevant to the modern generation of learners and all people. I take the analysis further by focusing on the student teachers' results as follows:

(b) Results from student teachers

The trend of ethnomathematics as a teaching strategy that depends on learners' cultural backgrounds and practices was further corroborated by student teachers' responses. In this regard, the results from the student teachers' pre-intervention questionnaire and focus group interviews revealed two perceptions regarding the understanding of ethnomathematics as a concept. The first perception strongly aligns with the teacher educators' perceptions of ethnomathematics as a teaching strategy based on the relationship between mathematics and culture (TE B1; B2; C1; & C6). For example, three student teachers commented that ethnomathematics is: "*The relationship between culture and mathematics*" (ST C1, PQ, Add I:123; ST C4, PQ, Add I: 135; ST C6, PQ, Add I:139). Furthermore, Student Teacher C4 elucidated that: "*Ethnomathematics…looks at how people carry out mathematical activities in the daily lives*" (ST C6, PQ, Add I:139).

The above quotations from student teachers illustrate participant perceptions that ethnomathematics focuses on mathematics found in people's sociocultural and environmental contexts. These perceptions propose that mathematics concepts and skills may be found in cultural practices. Thus, according to the student teacher participants, there are mathematics ideas embedded in people's everyday lives. The emphasis on such mathematics ideas found in learners' everyday activities could provide a link to CAPS mathematics by mathematising. In the same vein, ST B2 claimed that ethnomathematics uses "*culture to teach mathematics, or rather how we can incorporate culture in our teaching of mathematics"* (ST B2, TI, Add H:115). She further asserted that the integration of some cultural practices into the teaching and learning is necessary since they "*have mathematics in them"* (ST B2, TI, Add H:115). Thus, ethnomathematics appears to be concerned with *"how culture can impact the teaching and learning of mathematics*" (ST A2, FG, Add H:78).

Similarly, another student teacher added that ethnomathematics *"has to do with how cultures* [practices or activities] *can be used to teach the school mathematics"* (ST B3, ES, Add H:121). It provides teachers with opportunities to consider the cultural "*context of the learners*" (ST C4 & C6, FG, Add H:92-93) to contextualise mathematics. The contention, according to ST C1, is to *"have learners engaged in the lessons and to have … ideas that relate to what they already know*" (ST C1, FG, Add H:93). Thus, ethnomathematics puts emphasis on learners' "*prior knowledge or the things that they experience in their everyday life*" in learning mathematics (ST C7, FG, Add H:94).

The above quotations from student teachers demonstrate the participants' perception that ethnomathematics provides greater possibilities for using culture to teach or explain mathematics concepts. This goes hand-in-hand with Student Teacher B1's comment that ethnomathematics focuses on

> *how we could involve our cultural perspectives in the learning and teaching of mathematics ... when we are teaching our learners mathematics, we have to contextualise it for them. Contextualise it for them by using their cultural perspectives … we can try to integrate their tradition, their culture into mathematics education and learning.* (ST B1, TI, Add H:107)

He further expressed that: "*the whole idea of contextualising it is that we want to see mathematics at its cultural base as well. We want to integrate culture, their culture… into mathematics education while we are learning and teaching*" (ST B1, TI, Add H:107). The contention is that cultural contexts can be integrated to contextualise mathematics.

Although the second perception also acknowledges the relationship between culture and mathematics, it is influenced by '*ethno*' as a suffix from the Greek word which focuses on, amongst other things, ethnicity, beliefs, and culture and **'**mathematics**'** as a content subject offered in the schools (ST A3; A4; & C3). For example, one student teacher stated "*we have ethno and mathematics. Ethno is about the beliefs and ideas in culture. Then we have again the mathematics whereby this one is about the content… So, the relationship is about the culture and mathematical ideas* (ST A4, FG, Add H:78). In the same vein, ST C3 asserted that "*ethno is about ethnic groups and their culture. Mathematics is the study of relationship between quantities.*

Ethnomathematics therefore focus on the relationship between mathematics and culture" (ST C3, PQ, Add I:131).

Furthermore, Student Teacher A3 underscored that ethnomathematics is "*about the learning of mathematics and based on the different kinds of ethnicity…learning mathematics from different backgrounds in different cultures…the learning of mathematics based on culture and ethnicity"* (ST A3, FG, Add H:79).

The above quotations from the student teachers suggest participants' perceptions that ethno encapsulates all the specific cultural practices which may be linked to school mathematics. Thus, according to the student teacher participants, ideas, symbols, beliefs, methods, and practices found in different cultures may be connected to school mathematics (D'Ambrosio, 2016; Rosa & Orey, 2010). The contention is that the ideas various cultural groups apply to do measurements, for example, may be integrated into the teaching and learning of school mathematics. These perceptions propose that ethnomathematics is premised upon sociocultural contexts that can be used to contextualise mathematics.

Although some student teachers (ST C2 & C3) perceived ethnomathematics as the relationship between mathematics and culture, they acknowledged that they did not have a nuanced understanding of the concept prior the ethnomathematics workshop. For example, the results indicated that prior to the ethnomathematics workshop, some student teachers "*did not know what ethnomathematics was"* (ST C2 & C7, FG, Add H:92-93) and their understanding of the "*concept was vague"* (ST C3, FG, Add H:92). However, they felt positive that participation in the workshop developed their *"deeper understanding of what ethnomathematics means*" (ST C3, FG, Add H:92) and also shed a light on how ethnomathematics can be integrated "*during the lessons in the classroom*" (ST C2, FG, Add H:92). These perceptions acknowledge student teachers' limited understanding of ethnomathematics, regardless of their attempt to define the concept in the pre-intervention questionnaire where they perceived it as the relationship between mathematics and culture. Thus, their perceptions provide evidence that they did not have sufficient knowledge of what the relationship between mathematics and culture entails. In the next sub-section, I provide a synthesis of the teacher educators' and student teachers' findings informed by literature.

(c) Synthesis of teacher educators' and student teachers' findings integrated with literature

What can be understood from the teacher educators' and student teachers' findings above is that there is a general agreement that ethnomathematics is based on the relationship between mathematics and culture. Although findings from both teacher educators and student teachers, as quoted above, revealed the relation between mathematics and culture as the most recurring definition of mathematics, other teacher educators (TE A1 & TE C1) understood as a dynamic and evolving concept in the context of ethnomathematics. The findings from teacher educators suggest that ethnomathematics should be understood as a dynamic and evolving concept not only limited to mathematics concepts associated only with past cultural practices. The findings concur with the definition offered by Rosa and Orey (2010) which emphasised mathematical ideas found in any culture.

The findings also revealed that one teacher educator (TE A1) and some student teachers (ST A3; A4; & C3) perceived ethnomathematics as a combination of ethno and mathematics. The contention was that 'ethno' in ethnomathematics probably include ethnicity, cultural practices and structures, ideas, beliefs from specific cultural groups and mathematics as learned in school. This is often attributed to the D'Ambrosian perspective based on Greek etymology *ethno*, *mathema*, *tics* (D'Ambrosio, 1993; Rosa & Orey, 2016, p. 11). Thus, the findings revealed that various cultural backgrounds, structures, ideas, and practices may be considered in the teaching and learning of mathematics. The contention is that mathematics is embedded in culture and there is a need to explore mathematical processes and skills found in various cultures.

5.5.3 Summary of the sub-section

The findings of the study revealed that ethnomathematics is viewed as an indigenous way of doing mathematics. Teacher educators and the ethnomathematics expert's findings suggest that throughout human history, mathematics has always been part of people's daily activities. They believed that people of different cultures engaged in mathematical knowledge and skills to meet their everyday living needs. The contention is that mathematics could be traced back in human history and, as such, it should be viewed as a human activity. The indigenous houses, indigenous games, beadworks, and art, amongst others, tell a story of mathematics. Thus, the findings from semi-structured interviews pointed out that mathematics is found in various cultural practices and such cultural practices should have a place in the mathematics classrooms.

Furthermore, the perceptions also revealed that ethnomathematics focused on recognising the relationship between culture and mathematics and how such a relationship could be used in the teaching and learning of mathematics. Notably, the teacher educator participants perceived ethnomathematics as a dynamic and evolving concept not only limited to the past historical cultural references.

In the next section, I focus on the results concerning the participants' perceptions about the role or importance of ethnomathematics in the teaching and learning of mathematics.

5.6 PARTICIPANTS' PERCEPTIONS ABOUT ETHNOMATHEMATICS

In this section, I focus on the participants' perceptions about ethnomathematics. The teacher educators, ethnomathematics expert, and student teachers generally agreed that the integration of ethnomathematics may provide benefits for the teaching and learning of mathematics. Three themes emerged from the semi-structured interviews, pre-intervention questionnaire, and focus group interviews and revealed that the integration of ethnomathematics may:

(1) enhance learners' understanding of abstract mathematics concepts;

(2) develop learners' awareness of mathematics in real-life contexts; and

(3) develop awareness that every culture has contributed to mathematics development.

These perceptions are presented, discussed and interpreted below:

5.6.1 Theme 1: Ethnomathematics may enhance learners' understanding of abstract mathematics concepts

In this theme, the results from teacher educators, ethnomathematics expert, and student teachers are presented and interpreted. Firstly, I focus on the results from the teacher educators' and the expert's interviews. Secondly, I focus on the results from the student teachers' pre-intervention questionnaire, interviews, and focus groups. Lastly, I focus on the synthesis of the findings against literature.

(a) Results from teacher educators and expert

The results from teacher educators and the expert revealed that integration of ethnomathematics as a pedagogical strategy may enhance learners' understanding of mathematics. In this regard, one teacher educator participant expressed that *"some of the practices that are not in the school we overlook only to find those are the practices that can unlock the difficulties in terms of mathematics teaching and in terms of making mathematics accessible to learners"* (TE A2, F2F, Add G:30). In the same vein, TE B2 strongly believed that "*learners have problems in grasping maths…* [as] *it is presented in a western way in an abstract manner."* The contention is that teachers are not "*trying well enough or are not familiar with real life situation that links … directly to the abstract mathematics"* (TE B2, ES, Add G:56). These perceptions suggest that learners often find mathematics difficult as it is taught using only the abstract notation(s) which do not consider their (cultural/everyday) contexts. Thus, the teacher educators agree that teachers do not integrate learners' prior knowledge filtered from their cultural worldviews as part of teaching approaches.

Similar views were shared as follows by the expert participant:

> *The way math is taught in schools … it's taught for those chosen few like in the past… ethnomathematics it says, but with the knowledge that I have, I can … understand the maths concepts … when coming to contextualising … mathematics meaningfully, it also assists us* ***…*** *we bring … those concrete things to understand those abstract concepts in maths.* (E 1, TI, Add G:63)

He further explained that ethnomathematics values scenarios *"which one is familiar with, to teach the concepts"* (E 1, TI, Add G:63).

The expert participant's observation given above reveals that the teaching of mathematics in South African classrooms may be largely influenced by traditional philosophical orientation, which strongly consider mathematics as a subject for the chosen few. Teaching mathematics without considering learners' cultural or everyday backgrounds does not only create learning difficulties but may also exclude learners in the learning process. This exclusion could be addressed by appreciating and considering the cultural knowledge as a starting point towards learning and understanding mathematics. Such integration entails teaching abstract mathematics concepts using concrete examples drawn from learners' cultural practices or everyday lives. These perceptions suggest that ethnomathematics can concretise mathematics concepts and make them accessible to learners.

Furthermore, the results showed that the integration of ethnomathematics may not seek to reduce the abstract nature of mathematics but may create learning opportunities for learners to develop abstract thinking. In this regard, Teacher Educator C1 argued that

> *it's not always that actually we don't teach abstract; I think the reason for teaching mathematics is to reach abstraction…but you don't start at that point. You start at a point where you make learners understand by connecting whatever they know…bringing what comes from outside the classroom into the classroom by using their prior knowledge and build on.* (TE C1, TI, Add G:39)

This perception highlights the importance of integrating learners' knowledge derived outside their classroom into assisting them to understand the abstract concepts in mathematics. This suggests that teachers should consider learners' cultural backgrounds which constitute ethnomathematics as essential starting points towards establishing a connection of ideas in mathematics. Hence, the integration of ethnomathematics "*context brings relevance of mathematics to the students"* (TE C1, TI, Add G:40). Therefore, the integration of ethnomathematics in school mathematics does not undermine abstraction but facilitates its realisation.

(b) Results from student teachers

The results from the student teachers corroborated the trend of the role of ethnomathematics in promoting mathematics understanding. For example, Student Teacher A4 asserted that there are "*concepts which are most difficult in mathematics … we start learners from the concrete level whereby we don't start at an abstract level so that they will be able to understand the concept better*" (ST A4, FG, Add H:85). In this regard, the student teacher suggests that concrete examples from learners' sociocultural contexts can aid their understanding of abstract mathematics concepts. The result illustrates the participant's perception that learners' ability to make a meaningful connection of mathematics ideas is linked to the integration of sociocultural contexts.

Similarly, another student teacher emphasised that

> *if you just go abstract … some learners will not understand … if you start with difficult things, you are not including them, it will even make it very difficult for them to learn…examples from … [learners] … cultural backgrounds, it will help them to understand maths better.* (ST B2, Add H: 116)

The comments from the student teacher illustrate the participant's perception that mathematics concepts are deemed difficult when they are taught in abstract teaching methods. Thus, according to the student teacher, participant learners' sociocultural contexts may serve as a starting point towards understanding abstract mathematics concepts.

Furthermore, ST B3 pointed out that when *"learners learn … [mathematics] … using their surroundings and environment, it will be easy for them because they know those things"* (ST B3, ES, Add H:122). Similarly, another student teacher agreed that "*learners will understand mathematics content when we use what they know to teach them*" (ST C6, PQ, Add I:141). Similarly, ST C1 claimed that "e*xamples from learners' indigenous knowledge can make learners understand school mathematics*" (ST C1, PQ, Add I:124). These perceptions propose that the integration of ethnomathematics considers learners' knowledge from sociocultural contexts which they may relate with in the mathematics learning processes. The perceptions further infer that learners' knowledge drawn from their indigenous knowledge practices could play an essential role in assisting them to understand mathematics. Thus, according to the student teachers, the integration of ethnomathematics may develop learners' abilities to make connections and deepen their understanding of mathematics.

Similarly, ST A3 contended:

> *If you get to experience something in your comfort zone, when you teach maths through ethnomathematics you are going to the learners' comfort zone, to teach them where they feel comfortable … you speak what make sense to them; so, I think that's the reason we should promote ethnomathematics.* (ST A3, FG, Add H:84)

These perceptions from Student Teacher A3 illustrate the participants' perception that integration of ethnomathematics may provide learners with conductive learning environments. In such a learning environment, according to the student teacher participant, the teaching of mathematics is based on learners making sense of their learning experiences through the sociocultural contexts they are familiar with.

Furthermore, Student Teacher C4 claimed:

> *Learners will find mathematics more meaningful when it is based on IK, because it is built upon things which are relevant to their context. Thus, creating more interest and a deeper understanding of mathematics*. (ST C4, PQ, Add I: 136)

The above extract from ST C4 demonstrates the participant's perception that integration of ethnomathematics may create meaningful learning as it builds on learners' cultural or everyday contexts. The perception proposes that the knowledge learners may bring to their learner environments may help them to establish connection in mathematics.

In the next sub-section, I provide a synthesis of the teacher educators', the expert's, and student teachers' responses integrated with the literature.

(c) Synthesis of teacher educators', expert's, and student teachers' findings integrated with literature

What can be inferred from the findings of the teacher educator, the expert, and student teacher participants is the perceptions that ethnomathematics may enhance learners' understanding of mathematics. Mathematics is often regarded as a difficult subject for many learners. This may be attributed to transmission approaches that are dominant in many mathematics classrooms—teaching mathematics in purely abstract approaches (Alex & Mammen, 2014; Ardeleanu, 2019; Masilo, 2018; Siyepu & Mtonjeni, 2014). The findings revealed that innovative teaching strategies such as using ethnomathematics can help learners to understand abstract mathematical concepts. Thus, the participants strongly believed that ethnomathematics could provide a concrete lens that learners could use to understand the abstract concepts. The findings suggest that ethnomathematics may serve as a bridge from concrete to abstract levels of mathematics. The findings also suggest that at a concrete level, mathematics may be perceived from what learners know; their experiences and prior knowledge shaped by their culture may become a starting point towards developing mathematics understanding.

The findings further showed that the integration of ethnomathematics could help learners learn mathematics meaningfully and thus assist in conceptual understanding. Thus, when teachers use ethnomathematics as an instructional approach, learners may experience meaningful learning of mathematics. The use of examples and activities from learners' cultural backgrounds might help learners to understand mathematics concepts that are generally considered as abstract, according to the participants. The contention is that ethnomathematics provides opportunities for learners to learn mathematics at their comfort zone based on what they know and understand. The findings uphold the notion that ethnomathematics enhances the learners' ability to make meaningful connections and deepen their conceptual understanding of mathematics concepts (Moloi, 2015; Moloi et al., 2021; Nugraha et al., 2020; Rosa & Orey, 2016; Sharma & Orey, 2017; Spangenberg, 2020). In the next theme, I focus on perceptions related to ethnomathematics as a pedagogical approach to develop learners' awareness of mathematics in real-life.

5.6.2 Theme 2: Ethnomathematics may develop learners' awareness of the relevance of mathematics in real-life contexts

In this theme, the results from teacher educators, the expert, and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' and the expert's interviews. Secondly, I focus on the results from student teachers' pre-intervention questionnaire and focus groups. Lastly, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators and expert

The results from two teacher educators and the expert revealed that the teaching and learning of mathematics is generally characterised by a lack of focus on learners' real-life contexts. This creates an assumption that mathematics has no links to learners' real-life contexts. Consequently, learners might lack awareness of mathematics which can be drawn from their cultural backgrounds. In this regard, the participants pointed out that the integration of ethnomathematics could help learners to establish the link between mathematics and real-life contexts, developing their awareness of mathematics in real-life contexts. Thus, ethnomathematics may be considered as an approach to bridge the gap between mathematics and learners' cultural contexts. In this regard, the expert participant felt strongly that learners "*can't relate maths concept things to daily life … ethnomathematics …[is]… trying to assist us to bridge that gap"* (E 1, TI, Add G:63). Herein, it is important for learners to be aware that mathematics is "*linked to our everyday life or indigenous knowledge"* (TE B2, ES, Add G:56). The results revealed participants' perception that ethnomathematics may bring a connection between mathematics in everyday contexts and mathematics taught in schools.

Another teacher educator highlighted that in order for learners to develop awareness of mathematics in a real-life context, it is important that teachers should not "*teach learners about something that is not immediate in their environment*" (TE C1, TI, Add G:37). Similarly, an expert claimed, *"We look at the environment around us, there is huge wealth of knowledge, which we can use … to teach* [mathematics] *concepts"* (E 1, TI, Add G:64). The contention is that learners' awareness of mathematics in a real-life context can be driven by *"bringing what comes from outside the classroom into the classroom by using their prior knowledge and build on it"* (TE C1, TI, Add G:39)*.* Similarly, Teacher Educator A1 stressed that when learners *"learn maths from different context, not maths as pure as it is … [they can] … generate ideas from real life situations"* (TE A1, F2F, Add G:22). These perceptions propose integration of ethnomathematics as an essential pedagogical approach which may provide teachers with opportunities to utilise knowledge from the learners' sociocultural contexts where learners become aware of mathematics in their everyday contexts.

(b) Results from student teachers

The results from student teachers' focus groups supported the perceptions that ethnomathematics could develop learners' awareness of mathematics in their everyday context. Through the integration of ethnomathematics, learners may be able to study mathematics concepts in their real-life. One student teacher contended:

> *[Ethnomathematics] is advantageous for learners who don't know that mathematics exists in real world… I was one [of] the learners to say that maths was just a classroom thing. When we get out, there was no such thing but when we talk of maths existing like when they are at home, they saw like a tile...floor tile like then they use an area, that's when we know that maths exists*. (ST A2, FG, Add H: 85)

The above quotation from the student teacher demonstrates the participant's perception that most learners may not be aware of mathematics concepts and skills found in their everyday lives. Thus, according to the student teacher participant, learners often consider mathematics as only limited to the academic subject. This perception proposes that the integration of ethnomathematics may promote learners' awareness of mathematics in a real-life context. The emphasis appears to be that learners may become aware of mathematics found in their cultural backgrounds when they are taught through ethnomathematics.

Similarly, ST B2 contended that the integration of ethnomathematics allows teachers to *“have real life scenarios … [which they can] … apply”* (ST B1, TI, Add H:110) to explain mathematics concepts. As a result, learners will develop “*idea[s] how to use their everyday activities in conjunction with mathematics*” (ST C1, FG, Add H:93). These perceptions propose that teachers should take into “*consideration the indigenous knowledge and … the things that they experience in their everyday life*” (ST C7, FG, Add H:94) when contextualising mathematics.

Student Teacher B1 further demonstrated confidence in identifying mathematics concepts and skills found in various cultural practices:

> *If you look at mosque … the structure and the design, it has mathematics … mathematical principles like trigonometry, angles, Euclidean geometry … definitely integrated in some of the designs of mosque, the churches … the structure of it, the architecture behind it is definitely mathematics.* (ST B1, TI, Add H:109)

These results from ST B1 illustrate the participant’s perception to recognise mathematics concepts from sociocultural contexts. The contention is that mathematics concepts such as geometry and trigonometry may be identified from learners’ sociocultural contexts. Learners come from environments that are dominant with various cultural practices which have mathematics embedded within, according to student teacher participant.

(c) Synthesis of teacher educators’, expert’s, and student teachers’ findings integrated with literature

What can be inferred from teacher educators’, the expert’s, and student teachers’ findings is that ethnomathematics could help learners to bridge connections between school mathematics and mathematics from everyday life. Ethnomathematics as an epistemology dictates pedagogical approaches that could position the relevance of mathematics in our daily lives, according to the participants. The participants agree that learners need to be able to link mathematics knowledge from their cultural backgrounds to the mathematics in their classrooms. Thus, the findings suggest that learners may be able to make connections between mathematics as learned in the classroom and mathematics as experienced in their everyday life. The findings demonstrate that knowledge from learners’ real-life contexts and knowledge from their mathematics classroom need to link together. The findings further infer that the integration of ethnomathematics may provide learners with opportunities to develop analysis and reflection skills as they identify and interact with mathematics from their surroundings. The findings of this study concur with researchers such as Rosa and Orey (2016) and Namatovu (2015) that ethnomathematics could contribute to learners’ perceptions that mathematics is part of their everyday life. When learners’ cultural backgrounds are used in the classroom, they may experience mathematics as relevant and flexible (Moloi et al., 2021; Rosa & Gavarrete, 2016; Rosa & Shirley, 2016; Sharma & Orey, 2017; Spangenberg, 2020).

The next theme focuses on the results related to the participants' perceptions of ethnomathematics as an approach to develop awareness that every culture has contributed to mathematics development.

5.6.3 Theme 3: Ethnomathematics may develop awareness that every culture has contributed to mathematics development

In this theme, the results from teacher educators, the expert, and student teachers are presented and interpreted. Firstly, I focus on the results from the teacher educators' and expert's interviews. Secondly, I focus on the results from student teachers' pre-intervention questionnaire and focus groups. Lastly, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators and expert

The results from three teacher educators' and one expert participant's responses revealed that ethnomathematics may develop awareness that every culture has contributed to mathematics development. The results suggest integration of ethnomathematics in mathematics classrooms would likely serve as a unique opportunity for restoring and endorsing the already downgraded cultures in mathematics. In this regard, one teacher educator stressed that it *"is very important for our students to remember that it was not just one culture that contributed to the western number system, but a lot of cultures from different parts of the world"* (TE B2, ES, Add G:56). As a result, ethnomathematics empowers students (or learners) to appreciate that *"it is not only a certain culture [which] contributed to mathematics. Any other culture that we have can have that"* (TE C1, TI, Add G:40). These perceptions propose that the (Western) mathematics as known today is a culmination of numerous cultures from different cultural groups and such cultures should be utilised in its contextualisation.

The results further suggest a lack of cultural relevance as one the reasons linked to difficulties in motivating students to like mathematics. In this regard, Teacher Educator C1 argued that it *"is difficult to motivate students to like mathematics because they don't find relevance [as it] is not speaking to their culture"* (TE C1, TI, Add G:38). He further underscored that ethnomathematics rejects the notion that the teaching and learning of mathematics should merely focus on *"the traditional way … without considering the context and the culture"* (TE C1, TI, Add G:38). These perceptions propose that contributions of other cultures are largely marginalised in the mainstream school curriculum, particularly in South Africa. The mathematics found in different cultural practices is not given a place in the mainstream mathematics curriculum offered in schools. Western mathematics does not value and acknowledge the cultural contribution of other cultural groups. The perceptions illustrate that teaching and learning mathematics should reflect student cultures.

Furthermore, Teacher Educator A2 strongly believed that exclusion of other cultures in the teaching and learning of mathematics can be attributed to decolonisation. He claimed that some of the mathematics "*concepts … are not documented in the African way, the way we do things. They are westernised"* (TE A2, F2F, Add G:28). He went further to argue that

> *they come as if they are imposed on us. Like I am saying, some of it comes from us, is just that as we see it coming from them … they … bring the book, now it is their maths … We have a way of mathematics that we do is just that the issue of colonisation destroyed us a lot.* (TE A2, F2F, Add G:28)

The way in which African people mathematise is not documented and acknowledged in the mathematics curriculum. According to TE A2, this may create negative perceptions that African cultures have no relevance to mathematics as taught in schools. The contention is that colonisation which was driven by exclusion and undermining of other cultures, has destroyed the mathematisation methods found in cultural practices of indigenous people. The argument is that unique mathematics processes found within various cultural practices should be acknowledged and given a place in the teaching and learning of mathematics, according to Teacher Educator A2.

In the same vein, the expert participant highlighted concerns on our own (African) cultural exclusions by stating:

> *Can we see our cultural things in the curriculum we offer to our students, either be at school level … [or] … at the university level? We don't see ourselves there, there is nothing of our culture there … [ethnomathematics] allows everyone to have a voice in mathematics*. (E1, TI, Add G:68)

These comments illustrate the expert participant's perception that learners' cultural contexts are ignored and suppressed in the teaching and learning of mathematics. As a result, ethnomathematics foregrounds the inclusion of cultural contexts in the curriculum. The results provide evidence that ethnomathematics acknowledges the roots of mathematical knowledge from other cultures. The results further suggest that ethnomathematics advocate the accommodation of mathematics ideas and skills found in cultural practices in the curriculum.

Among the plausible elucidations for these results is that the mathematical voices from other cultures may be heard in the teaching and learning of mathematics through ethnomathematics.

To take the analysis a step further, the results also showed that ethnomathematics may promote the use of indigenous languages as part of embracing cultural restoration of previously managed cultural groups. The contention is that indigenous languages could facilitate learners' access to mathematics. In this regard, the expert participant qualified this claim with reference to Afrikaner culture, particularly on how they use their own language as a Language of Teaching and Learning. He noted that,

> *The Afrikaans people … the way they're teaching maths … they create those words such that they can understand. They bring them closer to their environment … They will tell you that "we can create it in our own way, the way we understand" … they have used what they understand. In other words, they define them in such a way they understand those words not saying they are losing meaning.* (E 1, TI, Add G:65)

Similarly, Teacher Educator C1 contended:

> *Eastern Asian countries, Japan, Singapore, and so forth…the reasons they keep getting better results is because they learn in their own languages that they speak at home. So, it's not like they transit when they go to school and speak another language. So, that's very, very important if they could learn in that language. It would have different results.* (TE C1, TI, Add G:45).

The above quotations from the expert and teacher educator indicate participants' perception that the use of indigenous language to teach mathematics means that learners will be able to comprehend mathematics concepts. According to the participants, one of the reasons learners are performing poorly in mathematics could be attributed to the language of instruction, suggesting a possible link between language and achievement in mathematics. The transition from indigenous language to English may create difficulties for learners to learn mathematics concepts. Thus, the use of indigenous languages could make a difference in learners' achievement in mathematics. The contention is that mathematics can be taught in Sepedi, Tshivenda, isiNdebele, isiZulu, IsiXhosa, and other indigenous languages as Language of Learning and Teaching (LOLT) without losing meaning. These indigenous languages are dominantly spoken in South Africa cultures. However, when learners enter mathematics classrooms, they are subjected to minority spoken languages such as English and Afrikaans as LOLT. This also highlights that the mathematics assessments do not take into consideration indigenous learners' languages, evidence of exclusion of other cultures. The results provide evidence that the integration of indigenous languages in mathematics teaching can facilitate restoration of learners' cultures in contextualising mathematics.

However, one teacher educator noted a major challenge towards the use of African or indigenous languages in mathematics. He felt strongly that *"the* [African] *language in the mathematics is not yet analogue…How are you going to teach maths in an African language? if that can be taken care of…then [we] can have a way"* (TE A1, F2F, Add G:28). This challenge illustrates the participant's perception that indigenous languages are not yet mathematically developed or standardised. The contention appears to be that mathematics concepts and procedures should be written, documented, and developed in African languages, according to the participant. More effort should be directed to develop mathematics teaching and learning resources in indigenous languages. Thus, the integration of ethnomathematics may create a pathway for indigenous languages in the teaching and learning of mathematics.

(b) Results from student teachers

The trend of ethnomathematics as an approach to promote inclusion of sidelined cultures in mathematics learning was further revealed by a few student teachers (ST A3; B1; & B2). For example, one student teacher asserted that the integration of ethnomathematics could serve as "*one way of teaching mathematics to motivate learners for inclusive education, to make them feel included in mathematics*" (ST B1, TI, Add H:110). Similarly, Student Teacher B2 underscored that when contextualising mathematics "*using [learners'] culture, they feel like they own it… When they feel that way, then I think that's the important part of teaching"* (ST B2, TI, Add H:118).

The above quotations from student teachers highlight the participants' perception that ethnomathematics is premised towards inclusion of every learner in the mathematics classroom. When learners learn and experience mathematics from their cultural worldviews, they not only feel a sense of inclusion but ownership, according to the participant. The participants believe that the teaching and learning of mathematics should acknowledge and embrace learners' cultural contributions.

Furthermore, Student Teacher A3, whose perception strongly agreed with the expert's and teacher educators' perceptions on indigenous language, underscored that it *"is easy for them to be learning…using their comfortable language"* (ST A3, FG, Add H:84). This perception proposes the use of indigenous language may enhance learners' understanding of mathematics. Thus, the participant maintained that mathematics concepts may be easily understood when learners learn through indigenous language as a Language of Learning and Teaching, according to the participant. In the next sub-section, I provide a synthesis of the teacher educators', the expert's, and student teachers' findings integrated with literature.

(c) Synthesis of teacher educators', expert's, and student teachers' findings integrated with literature

What can be deduced from the above four teacher educators', expert's, and three student teachers' findings is that many cultures—and not only one (Western) culture—have contributed to mathematics. Thus, a representation of these cultures in the mathematics curriculum is a necessity. The findings of this study concur with various researchers' assertions that mathematics is an offspring of culture (D'Ambrosio, 2016; Gerdes, 2014; Moloi et al., 2021; Rosa & Shirley, 2016; Sharma & Orey, 2017). Among the plausible explanations for these findings is that there are multiple ways of doing mathematics found in different cultures.

The findings further reveal that the Western mathematics curriculum offered in the schooling system often under-represent contributions from other cultures, in particular African cultures. Such under-representation is understood to have destroyed and undermined the way in which cultural groups mathematise. The findings concur with the argument raised in D'Ambrosio's (1985) theoretical work on the ethnomathematics and its place in history and pedagogy of mathematics:

> In many cases it never gets formalised, and the practice continues to the culturally differentiated group which originated it. The mechanism of schooling replaces these practices by other equivalent practices which have acquired the status of mathematics, which have been expropriated in their original forms and returned in a codified version. (p. 47)

Although the African way of doing mathematics as found in cultural practices may not be documented, it should not be discriminated against but be given a place and acknowledged in the mainstream mathematics curriculum to advance the development of learners in and outside the classrooms. Among the possible expositions for these findings is that ethnomathematics does not necessarily seek to replace western mathematics but makes it accessible by considering and valuing all cultural contributions.

The findings further provide evidence that when learners' cultures are represented in the mathematics curriculum, they become motivated and know that their cultures are valued in the teaching and learning of mathematics. The contention is that integration of learners' cultures though ethnomathematics could develop their sense of mathematical ownership. Among the plausible explanations for these findings is that learners might acknowledge the influence and role of their culture(s) in mathematics learning endeavours. The findings of this study concur with Van der Walt et al.'s (2019) assertion that when learners learn to see mathematics only from a western perspective, they may believe that their culture is less powerful and might not work with mathematics or, even worse, that they cannot work with the mathematics that they see in schools, as it is not their own. D'Ambrosio and Rosa (2017) pointed out that ethnomathematics does not only advance peace, but cultural inclusions of previously colonised epistemologies in the teaching and learning of mathematics.

Furthermore, the findings revealed that when learners learn mathematics using their language, they may understand mathematics concepts. The findings indicate that learners might find mathematics a difficult subject as it is not taught using their own language. The findings provide evidence that learners who learn mathematics in languages other than their own become disadvantaged. In many South African classrooms, mathematics is not taught in learners' home language. Furthermore, the findings highlight that ethnomathematics promote the inclusion of learners' indigenous or home languages in mathematics teaching. When learners are taught mathematics in a language that they understand, it may strengthen their abilities to make sense of mathematics. Mpalami (2022) recently found that the use of indigenous languages has an impact on learners' understanding of mathematics, which agrees with the findings of the current study. Mosimege (2017) also found that learners become more comfortable using their indigenous language in demonstrating mathematics concepts. One of the reasonable elucidations for these findings is that ethnomathematics seeks to empower mathematics learners through using their own indigenous language(s) they know and understand.

5.6.4 Summary of the sub-section

In summary, this section explored the teacher educators', the expert's, and student teachers' perceptions about ethnomathematics. What was evident from the participants' findings is the positive perceptions about the importance of integrating ethnomathematics in the teaching and learning of mathematics. The participants were of the view that ethnomathematics has a place in mathematics classrooms. The findings revealed that teacher educators, the expert, and student teachers believed that ethnomathematics could not only raise student awareness of mathematics in their everyday life but may also enhance learners' understanding of abstract mathematics concepts. The next section focuses on the results related to student teachers' preparation for ethnomathematical perspectives.

5.7 PREPARATION OF STUDENT TEACHERS FOR ETHNOMATHEMATICAL PERSPECTIVES IN PRE-SERVICE MATHEMATICS TEACHER EDUCATION

Mathematics teacher education is perceived as "a strategic place for debate and experimentation with cultural embedding of mathematics education" (Gerdes, 2014, p. 147). Gerdes' assertion illustrates that teacher education may be regarded as a starting place towards preparing students for ethnomathematical perspectives. Thus, teacher educators' knowledge and expertise are important for transforming the way in which ethnomathematical perspectives are integrated in mathematics education curricula. Thus, for ethnomathematics to be effectively integrated in the mathematics classroom, pre-service teacher education should prepare student teachers in ethnomathematics. Three themes emerged from the semi-structured interviews, pre-intervention questionnaire, and focus group interviews pertaining to preparing student teachers for ethnomathematics:

(1) Lack of focus on ethnomathematics in mathematics modules;

(2) Integration of diverse cultural techniques, indigenous games, and music to prepare student teachers in ethnomathematics pedagogical knowledge and skills, and

(3) The need to prepare student teachers in ethnomathematics towards changing their mindset about the teaching and learning of mathematics.

These themes are presented and discussed separately in the next sub-sections.

5.7.1 Theme 1: Lack of focus on ethnomathematics in pre-service mathematics teacher education

In this theme, the results from document analysis, teacher educators, and student teachers are presented and interpreted. Firstly, I focus on the results from document analysis pertaining to ethnomathematical perspectives in pre-service mathematics teacher education at selected universities. Secondly, I address results from teacher educators' interviews. Next, I discuss the results from student teachers' interviews and focus groups. Lastly, I focus on the synthesis of the findings integrated with literature.

(a) Results from document analysis on the integration of ethnomathematical perspectives at selected universities

The examination of pre-service mathematics teacher education documents such as universities faculty/school of education calendars, mathematics education course outlines, and mathematics education course guides have shown that ethnomathematical perspectives in mathematics education modules are not prioritised or included directly at selected universities. For example, results from University A's School of Education calendar revealed that the second-year method of mathematics, science and technology teaching module in Senior and Further Education and Training phases focuses on "*Interpretation of Policy documents and other literature to guide facilitation of learning on:* ***…*** *What is MST?****...*** *How do learners learn MST? (Focus on learning styles) … how should MST be taught? (Focus on teaching in context, teaching strategies)*" (University A, DA, Add J:149).

In addition, at University C there is a pedagogy module for each Bachelor of Education programme (Intermediate, Senior, and FET phases), which addresses the same knowledge areas in third year. For example, these modules focus on "teaching in context [and] [v]arious approaches to the teaching of Mathematics" (University C, DA, Add J:149). What distinguishes the modules at University C is the integration of CAPS mathematics content; for instance, the pedagogy module for the FET Phase focuses on knowledge areas "*linked to [FET mathematics] subject content*". The same applies for Intermediate Phase and Senior Phase (University C, DA, Add J:150). These results imply the emphasis in pre-service mathematics pedagogy modules is on equipping student teachers to teach mathematics in context. This may be a possible reason to integrate CAPS mathematics content in pedagogy modules, which would appear to be in line with the National Policy Framework For Teacher Education and Development in South Africa (DBE, 2006). Similarly, MRTEQ considers this integration essential as "it gives renewed emphasis to *what* [CAPS mathematics content] is to be learned and *how [pedagogy]* is to be learnt" (DHET, 2015, p. 9). Hence, how mathematics should be taught is influenced by an interpretation of the CAPS policy document, as evident in University A's School of Education calendar (University A, DA, Add J:149) and University C mathematics education modules (University C, DA, Add J:149), quoted above.

Although knowledge areas covered in pedagogy modules at both Universities A and B maybe relevant for integrating ethnomathematics, there is no evidence of how learners' cultural practices can be used to contextualise CAPS mathematics in IKS or learners' cultural contexts. Furthermore, while the issue of teaching [mathematics] in context is addressed in the modules, it emphasis is mainly on the theoretical rather than practical pedagogical aspects.

To take the analysis further, a focus on "[re]*sources for quality teaching and learning of Mathematics*" (University C, DA, Add J:150) may also be appropriate for integrating ethnomathematics artefacts such as indigenous games to contextualise mathematics. However, there are no references to resources from learners' IKS or everyday contexts in the pedagogy module content at University C. Thus, emphasis on resources in mathematics teaching and learning do not account for resources found in learners' cultural backgrounds.

Moreover, the results revealed that content and pedagogy are also integrated in the modules in University B. For example, one third year module related to Mathematics Intermediate Phase: Space and Shape, focused on "*developing student teachers' ability to identify the orientation and transformation of objects in space and to analyse and describe these transformations mathematically*" (University B, DA, Add J:150). The results insinuate that the focus in Mathematics Intermediate Phases is on equipping student teachers with both knowledge of geometry concepts and how to describe them to their prospective learners. This module may also be appropriate to integrate ethnomathematics, particularly to sensitise student teachers on how they can integrate learners' cultural or everyday contexts to describe geometry concepts such as transformation. However, such contexts may be integrated as an individual teacher educator pedagogical decision, particularly on methods they expose their student teachers to. Thus, integration of ethnomathematics in all three selected universities may be perceived as individual teacher educators' initiative on tools or resources they use to contextualise mathematics. In other words, teacher educators may decide which contextual scenarios to use in their modules.

On the contrary, a mathematics module at University B focusing on numeration systems and number theory exposes student teachers to "*different numeration systems such as Mayan, Roman and Egyptian systems*" (University B, DA, Add J:150). The results suggest that this module is appropriate to integrate ethnomathematics in pre-service mathematics teacher education, as it focuses on mathematics procedures and techniques found in various cultural groups. Thus, the module focuses on equipping student teachers only on how various cultural groups presented and calculated within their number systems.

(b) Results from teacher educators

Although some teacher educators hold positive perceptions about the role of ethnomathematics, the results from the Study guides revealed that they do not integrate ethnomathematics in mathematics education modules in University A and University C. For example, Teacher Educator A1 stated that he is "*not using any ethnomathematics in the teaching of my method subjects"* (TE A1, F2F, Add G:17). Similarly, Teacher Educator A3 underscored that *"ethnomathematics or indigenous knowledge is not one of the module outcomes in my module. As a result, we do not* *really focus on it"* (TE A3, ES, Add G:51). However, she further claimed that there is an attempt to *"refer to cultural backgrounds that could be used in making mathematics accessible without exploring in detail what mathematical ideas or constructs are embedded in such cultural backgrounds."* In the same vein*,* Teacher Educator A2 also acknowledged that they make reference to learners' cultural contexts *"but not frequently ... [and] not in details. Like someone would go and say your geometry and you look into the* [traditional houses/murals] *paintings"* (TE A2, F2F, Add G:26).

The above quotations from Teacher Educators A1, A2, and A3 demonstrate participants' perception that they do not integrate ethnomathematics in their mathematics education modules in pre-service teacher education at University A. One possible reason for such a lack may be attributed to module outcomes, as evident in TE A3, ES, Add G:51, quoted above. Thus, the results infer that integration of ethnomathematics is not compulsory in the pre-service mathematics education curricular at University A. The teacher educators do not focus on the role of ethnomathematics in contextualising mathematics whereby sociocultural contexts are used in the teaching and learning processes. In this regard, the results suggest that the teacher educators do not make provision for a broader application of cultural contexts that are situated outside of the mathematics classrooms.

Furthermore, teacher educators' perceptions suggest that cultural contexts are referred to without being given details on how they can be used as a pedagogical tool. A mere reference to geometry linked to paintings in cultural contexts, without in-depth analysis of how such contexts can be used to teach mathematics, as echoed by Teacher Educator A2 (TE A2, F2F, Add G:26), quoted above, suggests the extent to which ethnomathematics is not integrated in mathematics education modules.

Teacher Educator C1 claimed:

> *what we do and what we say is different. Because if we want the student teachers or teachers to use the culture in their teaching, we need to do so as…lecturers…Because if we don't do that, the teachers are going to do what we are doing… We need to change our way of doing things, so that… they can do what they see us doing. They can practise it while they are at universities and then leave and do it when they are with their students*. (TE C1, TI, G:39-40)

The above quotation of Teacher Educator C1 further illustrates the participant's perception that a focus on culture in mathematics is mainly done in a transmission strategy. In this regard, he stressed that telling student teachers what to do in terms of integrating culture is not sufficient;

instead they must be shown how it can be done. Thus, according to Teacher Educator C1, they should expose student teachers to teaching and learning theories, and pedagogical knowledge, amongst others, to legitimise mathematics knowledge situated within sociocultural contexts and how it can be used in the classroom. In this way, student teachers may be equipped with pedagogical knowledge to integrate ethnomathematics in their prospective classrooms. Thus, the results appear to suggest that the idea of integrating ethnomathematics in pre-service mathematics teacher education should be strengthened to prepare student teachers to contextualise mathematics.

The result further suggests that student teachers are likely to implement, in their prospective classroom, some topics/themes that they observed from their teacher educators, as evident in Teacher Educator C1 (TE C1, TI, G:39-40), quoted above. Thus, student teachers' integration of mathematics appears to be strongly linked to how teacher educators approach it in pre-service mathematics education modules.

(c) Results from student teachers

The trend of a scarcity of ethnomathematics in pre-service mathematics education in document analysis and teacher educators' results was further strengthened by student teachers, particularly from University A and University C. In this regard, one student teacher emphasised that the *"the methodology courses don't prepare us to incorporate ethnomathematics"* (ST A1, FG, Add H:83). Similarly, Student Teacher A3 pointed out that

> *Since the past three years I have been here, I don't remember any lecturer doing [ethnomathematics]. It was just teaching student teachers how to teach maths … but when coming to how to tackle ethnomathematics concept, it was something that would come, and we just pass by, just brush on it … It was never on the agenda that today or maybe this week we will be focusing on ethnomathematics.* (ST A3, FG, Add H:82)

Along the same line, Student Teacher C1 underscored that "*mathematics covered in Education do not prepare us for the use of ethnomathematics*" (ST C1, PQ, Add I:124). Furthermore, another student teacher asserted, "*our lectures never taught us about ethnomathematics*" (ST C6, PQ, Add I:140).

The quotations from three student teachers (ST A1, FG, Add H:83; ST A3, FG, Add H:82; ST C1, PQ, Add I:124; ST C6, PQ, Add I:140) suggest participants perceive that teacher educators do not prepare them to integrate ethnomathematics. These results highlight that student teachers are not equipped with knowledge and skills to use ethnomathematics. The contention is that the methodology modules focus on preparing them how to teach mathematics but without a demonstration of examples of how cultural backgrounds can be used in the classroom. However, issues related to ethnomathematics at times pop up in the discussion of concepts related to teaching and learning of mathematics, as noted by Student Teacher A3, quoted above. This was further reiterated by the same student, who emphasised that ethnomathematics aspects

> *came up as we were discussing…For example, if a student raises a point, and as a teacher [educator] answers that with something relational to whatever that is going on; that is when they bring the culture inside. It is not there in the guide.* (ST A3, FG, Add H:83)

Thus, the results indicate that ethnomathematics is partially used as an example, particularly in instances where issues related to cultural backgrounds somehow appear in the discussions.

Although other student teachers (STs C2; C3; C4; C6; & C7) agreed that they are not taught ethnomathematics, they emphasised that teacher educators prepare them to teach mathematics in context. For example, ST C4 asserted that "*mathematics education courses generally prepare us to contextualise mathematics. I would not say they focus on ethnomathematics or indigenous knowledge"* (ST C4, PQ, Add I:136). Similarly, another student teacher agreed that mathematics education modules "*do not teach us ethnomathematics. However, they teach us to contextualise mathematics*" (ST C3, PQ, Add I:132). In the same vein, ST C6 underlined that they "*do contextualisation where we are taught to teach mathematics in context*" (ST C6, PQ, Add I:140). However, these student teachers did not substantiate their perceptions with relevant examples on how mathematics can be contextualised. These perceptions appear to corroborate document analysis which revealed a focus on teaching in context, as mentioned previously (University C, DA, Add J:149). While teaching in context may be appropriate to mathematise CAPS mathematics through ethnomathematics contexts, this area appears to be silent, as evident in the student teachers' perceptions.

Furthermore, another student teacher highlighted that they are taught to "*contextualise mathematics by using learners' background knowledge or practical examples that learners can relate with* (ST C2, PQ, Add I:128). Although this perception appears to suggest learners' background knowledge or practical examples may suggest inclusion of everyday or IK context to contextualise mathematics, the student teacher felt teacher educators "*do not teach … ethnomathematics*" (ST C2, PQ, Add I:128). One reason that may possibly be linked to Student Teacher C2's assertion of not being prepared in ethnomathematics could be teacher educators who encourage them "*to contextualise mathematics, but they are just telling… without showing… how we can do it"* (ST C3, FG, Add H:94). Thus, according to student teacher C3, emphasis on telling them to integrate learners' cultural backgrounds rather than demonstrating how such integration can be done does not necessarily mean such integration encapsulates ethnomathematics. The results suggest that ethnomathematics should be demonstrated through active participation in examples of ethnomathematics in a practical way where student teachers learn how to mathematise CAPS mathematics using cultural artefacts or resources. The contention is that contextualising mathematics in learners' cultural backgrounds without detailed emphasis on how such contexts link with school mathematics cannot be considered as ethnomathematics. Although ethnomathematics focuses on sociocultural contexts, a reference to such contexts without a broader analysis and application or examples may not represent ethnomathematics.

The results further revealed that a lack of focus on ethnomathematics in pre-service mathematics education modules leave student teachers under-prepared to integrate ethnomathematics in their prospective mathematics classrooms. In this regard, Student Teacher C2 claimed "*I do not have adequate information on how best I can use them to contextualise mathematics. Our lecturers tell us to use learners' cultural context, but they don't show us or give us examples that we can use*" (ST C2, PQ, Add I:128). Similarly, another student teacher commented: "*I do not know how to teach using ethnomathematics*" (ST C3, PQ, Add I:133). Furthermore, Student Teacher C7 also asserted that he does "*not have knowledge how I can use them in my teaching*" (ST C7, PQ, Add I:144). The quotations from student teachers illustrate participants' lack of knowledge in terms of using ethnomathematics in their own classrooms. Thus, according to the student teacher participants, they do not have pedagogical knowledge and skills to integrate ethnomathematics into the teaching and learning of mathematics. Hence, other student teachers have knowledge of "*various indigenous games[,] but … do not see how they relate to mathematics*" (ST C1, PQ, Add I:124). These perceptions further suggest that student teachers appear to have underdeveloped knowledge of mathematising CAPS mathematics through IK contexts, which further reveals a limited understanding of integration of ethnomathematics.

Furthermore, the results illustrate that although student teachers are often told to integrate learners' cultural backgrounds into the teaching and learning of mathematics, they do not have confidence in achieving such integration in their prospective classrooms because of their limited knowledge on ethnomathematics. Hence, Student Teacher A1 also raised a concern that his

> *challenge would be picking the right topic or the right idea to get the contextualisation based on the culture or the environment of that particular school. That would be a challenge to me because once you pick the wrong idea, that would be the end of it, and you will get the whole class lost.* (ST A1, FG, Add H:87)

The perception further suggests the use of irrelevant cultural contexts may lead to learners' confusion in the teaching and learning of mathematics.

Furthermore, the results illustrate the importance of equipping student teachers in ethnomathematics so that they are able to integrate it in their classrooms. Hence, one student teacher noted “*I do not have much knowledge on ethnomathematics. However, I am open to using the concept in the classroom*” (ST C4, PQ, Add I:136). This perception illustrates the student teacher’s desire and interest to learn how it can be realised in the teaching and learning of mathematics.

In the next sub-section, I provide a synthesis of the teacher educators’ and student teachers’ findings integrated with literature.

(d) Synthesis of document analysis, teacher educators’ and student teachers’ findings integrated with literature

What can be learned from both document analysis, teacher educators’ and student teachers’ findings is that ethnomathematics epistemologies are not integrated in pre-service mathematics teacher education at University A and University C. The teacher educators are not integrating ethnomathematics as part of teaching strategies for contextualising mathematics. Thus, the findings suggest that pre-service mathematics education modules do not equip student teachers with ethnomathematics. A lack of ethnomathematics may be attributed to module outcomes which do not include ethnomathematics as one of the knowledge areas in mathematics education modules, as pointed out by Teacher Educator A3 (TE A3, ES, Add G:51), quoted above. Among the possible expositions for these findings is that it is not part of the curriculum in pre-service mathematics education programmes at selected universities. It is important to note here that teacher educators develop their own curricula at each university. The findings further infer the pre-service mathematics education programmes at University A and University C leave student teachers under-prepared to identify, analyse and implement learners’ cultural backgrounds in their classrooms. The findings of this study support the earlier findings of the research conducted by Rosa and Orey (2013), that pre-service teacher education is often little to prepare these student teachers for integration of ethnomathematics.

Although student teachers are trained to contextualise mathematics using various contexts such as learners’ cultural background, there is no practical evidence regarding the specific cultural backgrounds and how they can be integrated into the teaching and learning of mathematics. The findings revealed that student teachers (e.g., ST C4, PQ, Add I:136) appear to have insufficient knowledge of mathematising CAPS mathematics through learners’ cultural or IK contexts. The aspects related to contextualising mathematics in learners’ cultural backgrounds, which may provide opportunities to integrate ethnomathematics, are not adequately addressed in practical ways in either University A or University C. The findings insinuate that teacher educators leave it to student teachers to find ways through which they may integrate learners' cultural backgrounds in their prospective mathematics classrooms. The findings concur with Moyo (2011) who underscored that the curriculum implementation rests with teachers with regard to integration of IKS.

When student teachers are not trained or prepared for ethnomathematics during their pre-service mathematics education, chances of integrating it in their prospective classrooms might fade away. The findings suggest a possibility of student teachers experiencing challenges or difficulties in integrating ethnomathematics, as they lack knowledge and skills on how to integrate it, as evident from student teachers quoted above. The finding provides evidence that a lack of knowledge in ethnomathematics suggests that student teachers may struggle to identify which cultural practices can be used to teach specific mathematics concepts. The findings of this study affirm Jagals and Van der Walt's (2016) argument that all teachers who have been raised, taught, and qualified through a Westernised scientific view do not necessarily have the relevant background, knowledge and understanding of exactly what ethnomathematical perspectives to include in the curriculum, or how to do so. Furthermore, the findings also reflect Orey and Rosa's (2007) earlier assertion that teachers' under-preparedness limits the possibility for integrating ethnomathematics into the mathematics classrooms. The findings of the present study further support Namatovu's (2015) contention that teachers' lack of knowledge on ethnomathematics may be attributed to pre-service teacher education programmes that do not prepare them to teach culturally diverse learners. Thus, the effective integration of ethnomathematics into the teaching and learning of mathematics may possibly depend on student teachers' preparedness and ability to identify and apply (e.g., develop lessons for teaching in their prospective classrooms) what cultural practices can be used in mathematics classrooms. Equally important, they need to be able to analyse such cultural backgrounds to extract mathematical concepts.

In the next theme, I focus on the results pertaining to some of the possible ways of preparing student teachers for ethnomathematics.

5.7.2 Theme 2: Integration of diverse cultural techniques, indigenous games, and music to prepare student teachers to contexualise mathematics concepts in learners' everyday contexts

The starting point of preparing student teachers for ethnomathematics in the teaching and learning process is the identification of the relevant techniques and tools that could support their pedagogical knowledge and skills. There are numerous ethnomathematics artefacts or resources or tools that could be integrated to contextualise mathematics concepts (D'Ambrosio, 2016; Moloi et al., 2021; Rosa & Shirley, 2016; Sharma & Orey, 2017; Spangenberg, 2020; Van der Walt et al., 2019). Thus, ethnomathematics is rich with cultural practices that can be integrated in mathematics classrooms. When student teachers are exposed to a variety of cultural contexts, they may develop pedagogical knowledge and skills that could help them to integrate ethnomathematics in their prospective classrooms. Three sub-themes emerged from semi-structured and focus groups interviews on how student teachers are prepared or trained in ethnomathematics through integration of:

(1) diverse cultural techniques and methods,

(2) indigenous games such as Morabaraba to teach 2-D geometry concepts, and

(3) music and boomwhackers - as a new perspective to the teaching and learning of common fractions.

The above listed sub-themes provide a basis upon which student teachers can learn how to integrate ethnomathematics in their prospective classrooms and are discussed as follows:

5.7.2.1 Teacher educator and student teachers are of the perception that integration of diverse cultural techniques and methods provide multiple ways of teaching and learning mathematics concepts

In this theme, the results from teacher educators and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' interviews. Secondly, I discuss the results from student teachers' interviews and focus groups. Lastly, I address the synthesis of the findings integrated with the literature.

(a) Results from teacher educators

Contrary to teacher educators who do not integrate ethnomathematics in pre-service mathematics education modules, the results from only one teacher educator from University B revealed that various cultural techniques are integrated in mathematics education modules to prepare student teachers to contextualise mathematics concepts. One teacher educator confidently emphasised that in the mathematics education modules, they "*definitely include the history of mathematics … we are on different cultures the way they represent numbers, calculations, ideas, and concepts … the symbols they used to do that*" (TE B2, ES, Add G:56). In addition, she elaborated that "*the number system we use in the so-called western Math, its origin is from the Hindu Arabic system"* (TE B2, ES, Add G:56). The perceptions from Teacher Educator B2 highlight that a focus on the history of education equips student teachers with some knowledge of the role of culture in the origin of mathematics concepts and procedures. This suggests that the integration of calculation techniques in sociocultural contexts may play a valuable role in the teaching and learning of mathematics.

(b) Results from student teachers

The results from the student teachers confirmed that they are prepared in ethnomathematics, particularly on how different cultural groups mathematise. Student teachers referred only to different cultures in multiplication. It is interesting to note that one student teacher from University B and the student teachers from University C who attended the workshop on Ethnomathematics presented by Teacher Educator B2 had some experience on contextualising mathematics in indigenous knowledge and mathematising it. In this regard, Student Teacher B1 recalled that they "*learned about different number systems, the history, the context. But where does it come from? They started teaching of the Egyptian culture and mathematics, and link between Egyptian culture, with all the signs and symbols"* (ST B1, TI, Add H:108). This perception highlights how various cultures contributed to the evolution of number systems. The emphasis was also on the connection between various cultures and mathematics. Thus, the mathematics education modules equipped student teachers with knowledge of how cultural practices and symbols link with the mathematics as known and taught in schools presently. The results suggest student teachers *"learned about how culture is integrated in mathematics"* (ST B1, TI, Add H:108) to some extent.

Student teachers from University C who attended the one-day workshop on ethnomathematics responded as that a focus on methods and techniques found in cultural practices such as

> *Egyptian* [multiplication] *method … showed us that we shouldn't be looking at content or concepts in one specific way, but then there are many ways in which we can view like the concepts and the way we can deliver them to our learners.* (ST C1, FG, Add H:97)

Similarly, ST C7 stressed that teachers *"should always have a practical way to teach … learners such that they understand deeply, not just … explain in one method"* (ST C7, FG, Add H:98).

These perceptions highlight that the integration of ethnomathematics through different practices and methods from different cultures provide possible alternative teaching and learning strategies regarding teaching-learning of multiplication only. In other words, student teachers should try different strategies and techniques found in different cultural practices in order to develop their prospective learners' understanding of mathematics. The argument is that the integration of ethnomathematics does not limit student teachers to one strategy but multiple strategies of explaining or teaching mathematics concepts such as multiplication. Multiplication was the only topic student teachers referred to.

Furthermore, the results revealed that the integration of different cultural techniques, which constitute ethnomathematics do not only provides learners with some alternative learning strategies but also reduces their reliance on calculators. In this regard, Student Teacher C2 underscored that "*cultural contexts such as Chinese multiplication method could really help learners to understand multiplication easier without even relying on the calculators"* (ST C2, FG, Add H:97). Similarly, ST B3 agreed: *"Some of the calculations do not require calculators, they are also fun to perform, and it will make learning fun for our learners"* (ST B3, ES, Add H: 121). These comments illustrate student teachers' perception that multiplication may be performed or computed without using calculators, using techniques found in various cultures. In addition, the results suggest the integration of techniques found in various cultures may not only develop learners' confidence in multiplication but may create exciting learning experiences.

In addition, Student Teacher C4 claimed:

> *different methods … show us how we can multiply. I know speaking personally, for the longest time multiplication and division were the ones I couldn't do from the top of my head. I have always used to have a calculator, so with the way, with the many methods … I also discovered that I can multiply without using a calculator.* (ST C4, FG, Add H:97)

The aforementioned quotation from Student Teacher C4 confirms Student Teachers C2 and B3 perceptions that learners are dependent on calculators when learning multiplication. However, Student Teacher C4 is confident that with the methods and techniques found in different cultures, calculations may be performed or computed without relying on electronic calculators. These perceptions propose that when student teachers integrate ethnomathematics through various cultural techniques in their prospective classrooms, it may enhance learners' cognitive abilities to perform arithmetic calculations without calculators.

(c) Synthesis of teacher educator and student teachers' findings integrated with literature

What can be inferred from the teacher educator and student teachers' findings is that the integration of ethnomathematics may equip student teachers with alternative teaching and learning strategies in their prospective classrooms. Through a focus on the history of mathematics, student teachers might perceive mathematics as enshrined in many cultures. For example, the student teachers strongly believed that multiplication in many cultures activities during the workshop helped them to develop knowledge, which pertains to alternative ways of teaching mathematics concepts. The use of various cultural techniques such as Chinese and Egyptian multiplication techniques provided student teachers with practical approaches to multiplication. The findings further uphold the perception that methods found in different cultural backgrounds provide opportunities for mathematics to be taught in different contexts (D'Ambrosio, 2016; Orey & Rosa, 2007; Van der Walt et al., 2019).

In addition, the findings from student teachers revealed teaching mathematics concepts such as multiplication using different cultural techniques may not only deepen learners' understanding of mathematics but provide them with opportunities to choose methods, which may support their learning. The contention is that learners may not need calculators when they learn multiplication using methods found in other cultures. Some student teachers, such as Student Teacher C 4, proposed that most of the learners (like him/herself) struggle to perform basic mathematics computations without calculators. In other words, learners are dependent on calculators than their cognitive abilities for basic computational skills. As a result, using different cultural techniques in the mathematics classroom may promote learners' cognitive abilities. Through integration of other cultural techniques, learners may develop confidence that they can perform basic mathematics computation skills.

5.7.2.2 Integration of indigenous games as a pedagogical tool to contextualise 2-D Geometry concepts

In this sub-theme, the results from teacher educators and student teachers are presented and interpreted. Firstly, I focus on the results from the expert's and teacher educators' interviews, then the results from student teacher interviews and focus groups – after the workshop. Lastly, I focus on the synthesis of the findings Integrated with literature

(a) Results from teacher educators and the expert

The results from the teacher educators revealed that indigenous games can be used as a tool to contextualise 2D Geometry concepts. In this regard, Teacher Educator B1 claimed:

> *I make contextualisation very much a part of my teachings in my mathematics education modules. I expose my students to pedagogy of play in our lectures, we do it through integration of indigenous games (e.g., Morabaraba and Ncuva) and puppetry. Indigenous games are a large part of various cultures with underlying mathematical principles. We integrate these games to teach various mathematics concepts like geometry and fractions.* (TE B1, ES, Add G:47)

The above-mentioned quotation from TE B1 highlights the participant's perception that contextualisation of mathematics is an essential aspect in the teaching and learning of mathematics. As a result, she integrates indigenous games, amongst other cultural artefacts, to contextualise mathematics. In other words, the indigenous knowledge contexts may play an essential role in contextualising geometry concepts. The results further demonstrate TE B1's understanding of ethnomathematics, particularly with regard to the aspect of contextualising mathematics. The contention is that there are mathematics concepts such as geometry and fractions, which may be taught from indigenous games. The results further suggest that student teachers are being prepared with pedagogical knowledge and skills (also on indigenous or everyday experiences) on how mathematics can be contextualised through pedagogy of play, which has some aspects of ethnomathematics.

Similarly, Teacher Educator B2 also stated that she

> *make[s] the students play African or any other game, and then from playing the game or drawing the game board, they actually embody, they use the hands as an extension of their brains, they embody for instance the 2-D geometry figures and when you then name the concepts of the figures that you get from that it is then easier for the learners to relate to it*. (TE B2, ES, Add G:57)

In this regard, the teacher educator provide opportunities for student teachers to become active in playing the game as well as drawing various geometry shapes. This perception is further revealed when student teachers engage in hands-on activities such as drawing shapes, their understanding of mathematical concepts become strengthened.

Similarly, Expert 1 participant also reflected on how he integrated indigenous games in his classroom as follows:

> *The game is played and from there we look at the content or maybe any maths content which is embraced within that, if we understand the game, the way it is played. Then if you are saying these are the mathematical concepts which I can extract from this, you have to explain how so…* (E1, TI Add G:76)

The above quotation from Expert 1 illustrates his perception that indigenous games provide opportunities to explore mathematics concepts. This perception further proposes the importance of explaining how mathematics concepts are identified from the indigenous games. Thus, for an expert participant the focus is not just on playing but strengthening learners' abilities to mathematise mathematics concepts from the indigenous games.

(b) Results from student teachers

The results from student teachers from University B and University C confirmed that the integration of ethnomathematics through indigenous games provide opportunities for exploring mathematics concepts. In this regard, Student Teacher B2 claimed:

> *In one of our modules the lecturers in explaining how to contextualise mathematics… used the Morabaraba games to demonstrate how we can teach mathematics. Well at first, I was bored because I was like, "Oh, what are we doing?" But then as time went by when we started with the activity … I was able to learn how games can be applied to teach geometry shapes.* (ST B2, TI, Add H:116)

The above-mentioned quotation from ST B2 demonstrates how indigenous games may be integrated into the teaching and learning of mathematics. In the same vein, Student Teacher B3 emphasised that "*Geometry shapes were explored from the game, and we did some activities based on the game"* (ST B3, ES, Add H:121)*.* These perceptions suggest that mathematical activities based on the indigenous games may play an essential role in ethnomathematics-based instruction. The contention is that cultural contexts should be integrated through practical ways where student teachers may engage in the process of mathematisation. Thus, according to student teacher participant, mathematics learning activities may provide opportunities for extracting geometry concepts embedded in sociocultural contexts. The results suggest the integration of ethnomathematics artefacts in pre-service mathematics education modules may develop student teachers' pedagogical knowledge on *"cultures and how we can use it in our classrooms"* (ST B3, ES, Add H:121). Hence, Student Teacher C8 asserted that *"using the Morabaraba game … learners are going to understand the content and it is going to be kept in their mind for a longer time*" (ST C8, FG, Add H:100).

The results revealed that the ethnomathematics intervention workshop facilitated by expert-others (Warford, 2011), offered student teachers at University C opportunities to experience how they may use indigenous games to teach mathematics concepts such as geometry. Some of the student teachers were familiar with the Morabaraba game but prior to the intervention did not know that Morabaraba could be used as a teaching and learning tool. For example, Student Teacher C1 elaborated as follows:

> *I played Morabaraba for the longest time. I was the undisputed champion … but I never thought of it in the context of mathematics. Even when Professor introduced the game … I didn't think of it in many ways that she did because she did not show us one way in which the game could be used but she came up with many ways in which we could use the game to teach … the reflections, rotations, and … the lines.* (ST C1, FG, Add H:99)

The aforementioned quotation highlights the student teacher's knowledge and confidence in playing the Morabaraba game. Student Teacher C1 also acknowledged that he did not have knowledge that Morabaraba might be used as an instructional strategy. Similarly, Student Teacher C3 also affirmed that she *"never thought that there is maths in the game"* (ST C3, FG, Add H:99). Furthermore, Student Teacher C2 added:

> *I did not know that we could use Morabaraba to teach learners about the [geometry] shapes … So, what I have learned is that this game we can use it … to teach different things like where the lines are intersecting, parallel, transformation and shapes.* (ST C2, FG, Add H:99)

These perceptions not only affirm student teachers' lack of awareness of mathematics in the indigenous games but also became aware of the valuable role played by indigenous games in contextualising geometry concepts. Hence, ST C7 strongly emphasised that "*as much as it is a game, there are mathematics concepts that can be taught*" (ST C7, FG, Add H:100). In other words, the integration of ethnomathematics through indigenous games can "*make* [learners] … *aware of mathematics in the whole process of playing the game"* (ST C4, FG, Add H:99). These perceptions highlight that the integration of cultural artefacts into pre-service mathematics teacher education modules may develop student teachers' awareness of mathematics as found in such artefacts. Thus, according to the student teachers, integration of indigenous games may help them to recognise geometry concepts linked to the game. Hence, Student Teacher C4 strongly believed that geometry "*shapes that the learners wouldn't initially see in the game*" can be taught through indigenous games (ST C4, FG, Add H:99).

Furthermore, the results revealed that student teachers (at University C) consider the integration of indigenous games as an effective tool towards creating a learning environment where learners may experience fun and become actively involved in their learning. In this regard, Student Teacher C8 believed that indigenous games can "*bring fun into the learning of mathematics*" (ST C8, FG, Add H:102; ST C4, FG, Add H:101; ST B2, TI, Add H:116). The contention is that "*associating maths with fun would also help the learners to be more interested in learning*" (ST C4, FG, Add H:101) and "*interact with each other"* (ST C7, FG, Add H:102). These perceptions propose that the integration of ethnomathematics will stimulate learners' interest in learning and active participation. Thus, the results suggest indigenous games may offer learners opportunities to take part in the construction of their own mathematics meanings where they do not passively receive knowledge from teachers. The integration of indigenous games may also foster collaborative learning where learners will share ideas in their learning process, according to Student Teacher C7.

Similarly, Student Teacher C3 contended:

> *When we played the game Morabaraba, like I'm very competitive…it reminded me of something that my coach said, he said that competition brings excellence, because you want to win, and you want to be better. So, you lose the first game, and you want to get better. So, in the case of the Morabaraba game, these are going to be learners who say, "Okay I got it wrong, but I am gonna adapt my strategy there and get it better." And they can use those same ideas in their schoolwork. Yes, you are going learn something new today; you might not understand it today, try it again. This doesn't only apply to maths but is just a general thing that if you try it again, you will figure it out.* (ST C3, FG, Add H:99)

The aforementioned quotation from Student Teacher C3 illustrates the participant's perception that life lessons linked with playing the Morabaraba indigenous game may offer opportunities for mathematics learning. The competitive attitude learners develop towards an indigenous game may be transferred to a problem-solving context in the teaching and learning of mathematics, according to the student teacher participant. In the same vein, Student Teacher C7 emphasised that

> *when you play that game, you have to be strategic … as I was losing I saw … how I was supposed to move the pieces (cows) and how I was supposed to play around such that I could block the opponent.* (ST C7, FG, Add H:100)

These perceptions show that learners' persistence and motivation derived from playing with their peers may help them overcome struggles or learning difficulties in solving mathematics problems. Thus, according to the student teacher participants, when learners fail in their initial attempt to solve the mathematics problems, there is a possibility that they may reflect on the strategies they used and keep on persisting until they successfully resolve the problem at hand. Hence, Student Teacher C1 strongly believed that the integration of indigenous games can be integrated "*in lessons* [to] *develop learners' cognitive development … [and] … give them strategic ways to think about the problems"* (ST C1, FG, Add H:99).

(c) Synthesis of teacher educators' and student teachers' findings integrated with literature

The findings of the study revealed integration of ethnomathematics in pre-service mathematics teacher education at University B. Thus, teacher educators (TE B1 & TE B2) equip student teachers with pedagogical knowledge and skills related to integration of ethnomathematics through pedagogy of play. There was a demonstration of how ethnomathematics through indigenous games can be integrated into the teaching and learning of geometry concepts in pre-service mathematics education during the one-day workshop (University C). The findings concur with Moloi et al. (2021) and Van der Walt et al. (2019) who found that mathematical concepts such as quadrilaterals can be taught through indigenous games.

The findings also revealed that effective integration of ethnomathematics requires student teachers to engage in mathematics activities and reasoning linked with sociocultural contexts, which are used to contextualise mathematics. The contention is that engaging in activities based on indigenous games may provide student teachers opportunities to mathematise. By so doing, the transition from playing the indigenous games to learning mathematics with indigenous games become established.

The findings further revealed that for student teachers such as ST C1, FG, Add H:99; the integration of indigenous games is essential towards learners' cognitive development. The findings of this study concur with earlier findings of research conducted by Moloi (2014), which noted that cultural or everyday contexts may help to perform high cognitive and synthesis skills.

Furthermore, although the findings showed that some student teachers (e.g., Student Teachers C1; C2 & C3) did not know that indigenous games may be used to teach mathematics concepts, the ethnomathematics workshop developed their awareness on how indigenous games may be integrated to contextualise geometry concepts. As a result, student teachers developed knowledge of how they can integrate indigenous games into the teaching and learning in their prospective classrooms. The findings provide evidence that student teachers consider ethnomathematics knowledge they acquire in pre-service mathematics education modules as valuable for their prospective classrooms. The findings support Balamurugan's (2015) and Seroto's (2012) recommendation that teacher education programmes should offer courses or workshops to popularise and sensitise mathematics (student) teachers in the use of ethnomathematics.

5.7.2.3 The student teachers are of the perception that music and boomwhackers bring a new perspective to the teaching and learning of common fractions

Only the student teachers at University C who attended the one-day workshop had some experience of how the integration of music and boomwhackers brings a new perspective into the teaching and learning of common fractions. In this regard, ST C4 claimed *"like learners when I think fractions, I also become frustrated because for so many years … [music and] boomwhackers bring a different perspective that we can use to teach learners about the [common] fractions"* (ST C4, FG, Add H:104). In addition, Student Teacher C1 claimed:

> *when you mention fractions to learners, they get so confused, they get so uneasy because it's a complex concept for them but then taking from this* [music] *exercise is that even most of the complex concepts can be simplified. That's what we saw with the [music and] boomwhackers … We are using learners' interest to build up on what they know because now we all like music … and now you are using it in your class. It becomes so exciting, it's a new experience and it's something we are not used to, and learners will not be bored in that particular lesson*. (ST C1, FG, Add H:102)

The above quotations from STs C1 and C4 illustrate the participants' perception that many learners experience difficulties and frustrations when learning fractions. Thus, according to the student teacher participants, the concept of fraction is a challenge for learners. As result, there is the perception that the integration of music and boomwhackers may alleviate learners' difficulties associated with the learning of common fractions. These perceptions propose that boomwhackers and music may offer learners exciting new learning experiences and alternative representations to the meaningful learning of common fractions.

Similarly, ST C3 expressed that

> *It was interesting to see how you use … [music and boomwhackers] … for [common] fractions, because fractions are the most difficult concepts to teach. It was interesting to see [common] fractions without them being depicted as like a cake, or muffins. Yes, we know muffins, we have seen the muffins, it's enough … Now we know [common] fractions are not just blocks; they can also be music*. (ST C3, FG, Add H:103)

This quotation reveals the student teacher's perception that fractions are not only difficult for learners but also teachers find fractions the most difficult concept to teach. Both teaching and learning difficulties linked with fractions suggest a need for alternative ways to approach fractions, according to the participants. Hence, another student teacher participant strongly believed music and boomwhackers bring "*a new way of teaching fractions; I think we have exhausted the whole pies, blocks, and charts*" (ST C6, FG, Add H:104).

Moreover, ST C7 strongly believed that

> *teaching learners with [music and] boomwhackers, introducing them to fractions using [music and] boomwhackers will help learners to become more strategic … the moment you make that beat, in a learners' mind [common] fraction will come up … learners will relate the beats and how we make music with the actual fractions as we were singing. (*ST C7, FG, Add H:104)

This quotation illustrates the student teacher's perception that contextualising fractions through boomwhackers, and music may develop learners' strategic thinking skills. The contention is that learners may be able to link music with fractions, and derive fractions from musical beats, according to Student Teacher C7. Thus, this perception further strengthens that "*we can use [music and] boomwhackers in order to teach fractions*" (ST C8, FG, Add H:96).

The above student teachers' findings point out that learners find it difficult to comprehend fractions, particularly because of the examples that were used to teach these concepts. The student teachers agree that teaching fractions through using music and boomwhackers may provide new learning experiences for learners. The teaching and learning of fractions are predominantly characterised by the use of charts and blocks as demonstration tools. Thus, in the view of student teachers, most of the learners are not used to the integration of music, in particular using boomwhackers in the context of common fractions. Through integrating music using boomwhackers, the concept of common fractions may be simplified and accessible for learners. The findings further infer learners might be able to relate fractions with musical notes. The findings of this study concur with findings of research conducted by Mbusi (2011) and Van der Walt et al. (2019) that music could be used to teach mathematics concepts such as fractions. Redman (2016) pointed out that when learners use dance and movement to learn concepts, they deepen their understanding of the content. In my study, it seemed to have the same effect.

Moreover, the integration of music through boomwhackers may also provide opportunities for active participation in the teaching and learning of fractions. Thus, learners could become actively involved in their learning environments. In addition, through music and boomwhackers, the learning environment becomes characterised by fun where learners are likely not to be bored, as noted by Student Teacher C1 and quoted above. Thus, according to the participants, music and boomwhackers do not only provide a new perspective but also exciting learning environments in the teaching and learning of fractions. The findings in this study support the findings of the research conducted by Van der Walt et al. (2019) concerning the role of music and boomwhackers in creating successful learning experiences for learners.

5.7.3 Theme 3: Teacher educators and expert acknowledge the need to prepare student teachers on ethnomathematics towards changing their mindset about the nature of mathematics

In this theme, the results from teacher educators, the expert, and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' and the expert's interviews. Secondly, I concentrate on the results from student teachers' interviews and focus groups. Finally, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators and expert

The results revealed that some teacher educators and the expert participant believed that student teachers have mostly been exposed to mathematics as an abstract and culture-free discipline in their school years. In this regard, Teacher Educator B2 highlighted that *"our students were taught in a western abstract way mathematics since grade R – Grade 12, and now we have … to convince students* [through ethnomathematics] *to change the way they have been doing things"* (TE B2, ES, Add G:58). The perception from Teacher Educator B2 strongly suggests that student teachers come into pre-service teacher education with the knowledge about mathematics as an abstract subject. The results suggest that student teachers' perceptions about mathematics may be classified within what Ernest (2009) termed as the traditional philosophical orientation, which perceives mathematics as abstract (refer to Table 2-1). As a result, ethnomathematics may play an essential role in changing student teachers' perceptions about mathematics as an abstract subject.

Along the same line, Teacher Educator A3 emphasised the need to focus on ethnomathematics in pre-service mathematics education as it has possibilities to:

> *help change their perceptions about mathematics as most of them think of mathematics as an abstract subject aligned with the platonist philosophy. They do not think of mathematics as shaped by different cultures. They do not seem to know there are other philosophical orientations associated with mathematics. So, exposing them to ethnomathematics will in a way orientate them towards new philosophical orientations in mathematics.* (TE A3, ES, Add G:52)

She further stressed the student teachers should have pedagogical knowledge on *"different philosophical orientations which have a huge impact in terms of how they view the teaching and learning of mathematics"* (TE A3, ES, Add G:52).

The above quotation from Teacher Educator A3 illustrates the participant's perception that student teachers perceive mathematics as an abstract and culture-free subject. Thus, according to Teacher Educator A3, such perceptions may need to be challenged and changed. The contention is that if student teachers' philosophical orientations are not changed, their beliefs about teaching and learning of mathematics may be affected. Simply put, the perception infers that student teachers who are influenced by Platonist perspective may structure their instructional decisions and strategies based on such perspective. As a result, the integration of ethnomathematics may have an influence on student teachers' beliefs about the nature of mathematics and the role of culture in the teaching and learning of mathematics.

Similarly, the expert participant further strengthened Teacher Educator A3's & B2's perceptions about changing student teachers' mindset in the following way:

> *There are two…perspectives. So, if you look at ethnomathematics … it's on a transformative perspective. If we look at the era, where we are coming from, we could call it as a … Platonist perspective, which maybe I can call it … traditional perspective. So, it is important that … [student teachers] ... change their mindset of saying…maths is not a human activity … we need to change their perspectives about mathematics.* (E 1, TI, Add G:68)

The above quotation from Expert 1 illustrates his perception that ethnomathematics may help student teachers to perceive mathematics as a human activity. Thus, the expert's perceptions imply that student teachers need to be exposed to both the traditional philosophical orientation and humanistic philosophical orientation of mathematics. The expert's argument is that student teachers should also be equipped with a humanistic philosophical orientation such that they may begin to see cultural contributions in mathematics.

Furthermore, Teacher Educator C1 strongly believed that the integration of ethnomathematics in pre-service mathematics education could assist in removing stereotypes student teachers may hold about the nature of mathematics: *"I think it's the role of universities to make sure that we expose students to cultural aspects … so that we remove stereotypes that they have"* (TE C1, TI, Add G:40).

The results further revealed that the integration of ethnomathematics in pre-service mathematics education may empower student teachers to transform the teaching and learning of mathematics in their prospective classrooms. In this regard, Teacher Educator B1 emphasised that it

> *will help* [student teachers] *transform their teaching. They need to know that there are a lot of innovative teaching strategies that most of them have been subjected to by their school teachers. It will help them to plan lessons based on learners' cultural backgrounds in a practical way.* (TE B1, ES, Add G:48)

In addition, Teacher Educator A2 also asserted that "*We tell them … 'Transform your teaching. Transformation is the key' … Our programmes should go that route … We need to be diverse in the teacher training to allow those learners to venture into the teaching in several ways"* (TE A2, F2F, Add G:29). These perceptions propose that the integration of ethnomathematics will empower student teachers to integrate learners' sociocultural contexts into the teaching and learning of mathematics. The contention is that the student teachers will develop pedagogical knowledge and skills to integrate ethnomathematics. Thus, according to Teacher Educators A2 and B1, ethnomathematics may be perceived as an innovative pedagogy, which will assist student teachers to transform their teaching.

(b) Results from student teachers at University C

The results from student teachers at University C, who attended the one-day workshop on Ethnomathematics, supported Teacher Educator A2, B1, and the expert's perceptions that the integration of ethnomathematics in pre-service mathematics education may play an essential role in transforming the teaching and learning of mathematics in their prospective classrooms. In this regard, Student Teacher C3 claimed that *"including ethnomathematics in pre-service teacher training is beneficial because instead of learning just to teach in one way based on traditional approach to teaching … it can help us develop competences in teaching mathematics differently"* (ST C3, FG, Add H:94).

Similarly, Student Teacher C6 argued that the integration of ethnomathematics in mathematics education modules may

> *give teachers the necessary knowledge and skills to incorporate ethnomathematics within their lessons. It will also help … education to move away … from the normal way of teaching mathematics … when they show us not to focus on abstract way or teaching things abstractly, but rather incorporate what they know, how they can do it in a different way.* (ST C6, FG, Add H:95)

In the same vein, another student teacher emphasised that when

> *ethnomathematics is being incorporated in our undergraduate mathematics courses … it is going to help us learn on how we can include indigenous knowledge and cultures into the teaching of mathematics of which is going to help learners learn mathematics in … using the indigenous knowledge.* (ST C8, FG, Add H:95)

The above quotations from Student Teachers C3, C6, and C8 (after the workshop) illustrate the participants' perception that integration of ethnomathematics in pre-service mathematics education may equip them with knowledge and skills to transform their teaching. The contention is that the teaching of mathematics should be transformed such that alternative teaching approaches are used rather than the traditional transmission teaching strategies. These perceptions propose that the teaching and learning of mathematics should not only be characterised by traditional transmission teaching strategies but also embrace cultural contributions. Thus, according to the participants, when they are prepared in ethnomathematics, they may develop knowledge and skills to use learners' sociocultural contexts in their mathematics lessons. The results suggest that the integration of ethnomathematics in pre-service mathematics teacher education may empower student teachers to be able to use it in their prospective classrooms. Hence, Student Teacher C1 underscored that

> *ethnomathematics within our courses … give us the best way in which we can teach. Not only the traditional way of us teaching, … the teacher standing on the board, always having your chalk; but then you can make mathematics fun for learners as well*. (ST C1, FG, Add H:94)

The perceptions suggest that ethnomathematics may be considered as an alternative pedagogy to traditional transmission strategies that are often used in mathematics classrooms, according to the participants.

In addition, Student Teacher C3 emphasised that ethnomathematics "*includes more practical things, and it will help us as future teachers to contextualise mathematics … it should be introduced as it is more practical"* (ST C3, FG, Add H:94). Similarly, Student Teacher C9 asserted that

> *ethnomathematics needs to be introduced where it brings in element of creativity. For example, we as students we are being told that we must bring media, but the thing is we miss the concept of which kind of media should we use when we come to classes and then get to teach learners. I believe, by…incorporating ethnomathematics it will also broaden our knowledge as to how we should use different cultural resources to teach mathematics.* (ST C9, FG, Add H:95)

This above quotations from Student Teachers C3 and C9 (after the workshop) illustrate participants' perceptions that student teachers are often taught to contextualise mathematics without demonstration of how they may use cultural contexts to teach mathematics. However, according to student teacher participants, emphasising that they should contextualise may not be sufficient compared to demonstrating how it could be achieved. Thus, the student teachers strongly believe that integration of ethnomathematics may equip them with practical ways so they can use learners' cultural backgrounds in contextualising mathematics.

(c) Synthesis of teacher educators', the expert's, and student teachers' findings integrated with literature

What can be understood from the teacher educator and expert participants' findings is that student teachers have been taught mathematics from the traditional philosophical orientation in their 12 years of schooling. Thus, according to teacher educators and Expert 1, student teachers have for most of their schooling been taught mathematics from the Platonist perspective. Thus, the findings suggest that they did not experience mathematics as a human activity during their schooling years, which limits their knowledge about the nature of mathematics. The contention is that student teachers' orientation about mathematics is more aligned with the traditional philosophical orientation than the humanistic philosophical orientation of mathematics. Both teacher educators and the expert participant felt strongly that the teaching and learning of mathematics have historically been isolated from student teachers' social and cultural backgrounds during their years, as learners in both primary and secondary schooling. Student teachers' perspectives about the nature of mathematics and how it is taught is influenced by their school experiences. As a result, teacher educators and the expert participant revealed the need to prepare student teachers in ethnomathematics, particularly to change their perceptions about the nature of mathematics. Consequently, if these perspectives are not changed, then they are likely to teach mathematics free from learners' social and cultural contexts. The findings of this study concur with earlier assertions by Rosa and Orey (2016) that an important characteristic of ethnomathematics is the transformational power it has to help rethink the nature of mathematics as it fosters the development of innovative approaches towards the teaching and learning of mathematics. Thus, the findings of this study strongly acknowledge that ethnomathematics could contribute towards changing student teachers' perspectives about mathematics and influence their future instructional practices in their classrooms. Hence, according to Van der Walt et al. (2019), there is a need to focus on "[student] teachers' PCK in their own local and IK contexts, and their own readiness to contextualise and mathematise it" (p. 220). The findings further confirm Gerdes's (2014) assertion that Mathematics teacher education is "a strategic place for debate and experimentation with cultural embedding of mathematics education" (p. 147).

The findings from student teachers (only those who attended the workshop on ethnomathematics) on the need to prepare them in ethnomathematics is more on the pedagogical than philosophical orientation. Thus, student teachers strongly indicated that preparation for ethnomathematics might help them to teach mathematics meaningfully, taking into consideration learners' cultural or everyday contexts. They are of the opinion that ethnomathematics might play an essential role in transforming their pedagogical approaches to the teaching and learning of mathematics. By so doing, the possibilities of creating effective learning environments characterised by active learners' participation may be realised (Moloi, 2020; Moloi et al., 2021). The contention is that once the student teachers' mindset about mathematics is transformed, then the manner in which they will teach mathematics in their prospective classrooms will also be transformed through ethnomathematics. In other words, findings from student teachers demonstrate that ethnomathematics may equip them with knowledge and skills to teach mathematics not in the way they experienced it during their schooling years. Thus, the phenomenon of 'apprenticeship of observation' defined by Lortie (1975) may not be associated with student teachers who are prepared in ethnomathematics. The findings concur with Petersen et al. (2020) who argued that failure to transform perceptions about pedagogical orientations will result in student teachers imitating the way they were taught in their school years.

5.7.4 Summary of the sub-section

In summary, this section of the current research explored the preparation of student teachers on ethnomathematics perspectives in pre-service mathematics education programmes. The findings revealed three key aspects: Firstly, the data showed a lack of preparation of student teachers in ethnomathematics. Pre-service teacher education programmes in universities such as University A and University C are not preparing student teachers in ethnomathematics. As a result, a lack of focus on ethnomathematics in mathematics education leaves student teachers under-prepared to integrate ethnomathematics in their prospective classrooms. On the other hand, the results of the study revealed that the other university studied, University B, prepares student teachers for ethnomathematics perspectives. Furthermore, the results of the study showed that participants believed that the ethnomathematics workshop at University C equipped them with what it means to teach through ethnomathematics. Lastly, the results of the study revealed that there is a need to prepare student teachers on ethnomathematics pedagogies.

In the next section, I focus on the themes related to the challenges that could hinder effective integration of ethnomathematics.

5.8 CHALLENGES TOWARDS INTEGRATION OF ETHNOMATHEMATICAL PERSPECTIVES IN PRE-SERVICE TEACHER EDUCATION PROGRAMMES

Although ethnomathematics offers valuable benefits, there are numerous challenges that could hinder its integration into the teaching and learning of mathematics. Six themes emerged from the semi-structured interviews, focus group interviews, and pre-intervention questionnaire pertaining to challenges towards integration of ethnomathematics:

(1) cultural diversity;

(2) curriculum responsiveness;

(3) lack of contextualised curriculum resources;

(4) mentor teachers' discouragements;

(5) technology approaches; and

(6) time-consuming.

These challenges are presented, discussed and interpreted below:

5.8.1 Theme 1: Cultural diversity may hinder integration of ethnomathematics in the classroom

In this theme, the results from teacher educators and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' interviews. Secondly, I address the results from student teachers' interviews, pre-intervention questionnaire, and focus groups. Lastly, I provide synthesis of the findings integrated with the literature.

(a) Results from teacher educators

South African mathematics classrooms consist of both teachers and learners from diverse cultural backgrounds. The results revealed that the cultural diversity could hinder effective integration of ethnomathematics in the teaching and learning of mathematics. One main challenge is towards accommodating every learner's cultural background in the learning processes. In this regard, Teacher Educator A3 felt strongly that *"learners whose culture is not used will likely feel … under-represented"* (TE A3, ES, Add G:52). In such instances, learners might feel that their cultures are not valued in the classroom. In addition, Teacher Educator A1 emphasised that it *"is not possible to accommodate all of them, but you need to accommodate the majority of the students"* (TE A1, F2F, Add G:22). Thus, learners come to classrooms with unique cultural backgrounds which consist of practices, methods, symbols, and skills that can be integrated in the mathematics learning environments.

The aforementioned quotations from teacher educators A1 and A3 emphasise participant perceptions that teachers may experience challenges in identifying and selecting cultural contexts that would provide opportunities for all learners to actively participate. In other words, learners might struggle to mathematise from cultural contexts that they are not familiar with. This suggests that it is important for learners to have knowledge of cultural contexts that will be used as reference points in contextualising mathematics. As a result, teachers should integrate cultural contexts most of the learners in the classroom will relate with.

Nevertheless, Teacher Educator A3 felt strongly that the challenge imposed by cultural diversity should not necessarily be the basis for disregarding "*the importance of starting from learners' cultural backgrounds when teaching mathematics"* (TE A3, ES, Add G:52). This suggest that the benefits of integrating learners' sociocultural contexts outweigh the challenges imposed by cultural diversity. In order to circumvent this, student teachers should have knowledge of learners' diverse cultural backgrounds present *"in the classrooms and come with strategies which could work on their advantage in teaching mathematics within multicultural environments"* (TE A3, ES, Add G:52). Among the plausible elucidations for these results is that student teachers should have been taught how to use learners' sociocultural or everyday contexts during pre-service teacher education or through professional development by the DBE. Similarly, Teacher Educator C1 pointed out that when *"you are teaching a mathematics concept, you can ask learners from different cultures to explain what it means or how they say it in their culture*" (TE C1, TI, Add G:44). These perceptions propose that diverse cultural backgrounds provide opportunities for learners to explain mathematics concepts from their own cultural viewpoints. The contention is that teachers should create learning environments where learners will be free to express their ideas based on their unique cultural backgrounds. This way, teachers will be catering to the diverse cultural backgrounds within the classroom. As a result, learners may develop confidence in communicating mathematics ideas in the ways they understand better.

(b) Results from student teachers

The trend of cultural diversity as a challenge to the integration of ethnomathematics was further supported by student teachers. In this regard, Student Teacher A4 argued that learners "*are coming from different cultural backgrounds [and] challenge might be that if the teacher is introducing the…concept, some of the students might not understand"* (ST A2, FG, Add H:86). Similarly, Student Teacher C4 claimed: "*Some learners may not know the culture that their teacher is using in the lesson*" (ST C4, PQ, Add I:137). Similarly, Student Teacher C1 contented: "*Learners are from different cultures and may not know the cultural context you want to use*" (ST C1, PQ, Add I:125).

The aforementioned quotations from the student teachers illustrate the participants' perceptions that learners may have inadequate knowledge of sociocultural contexts that the teacher integrates into the teaching and learning of mathematics within multicultural classrooms. The contention is that the use of cultural contexts, which learners are not familiar with may create barriers towards understanding mathematics concepts. Similarly, another student teacher pointed out that when the cultural context *"is not known in that setting, it will not make any sense … How would you make them understand maths? because you will only confuse them … it is not working for them*" (ST A3, FG, Add H:82). Although the teacher may attempt to "*explain it to them, it just gives them even more confusion to say they are not able to see the link*" (ST C4, FG, Add H:101). However, well-trained student teachers will be able to explain the cultural aspects being used to contextualise mathematics in such a way that will promote learners' understanding.

The results suggest that the cultural contexts used in contextualising mathematics might confuse learners, especially when they do not have knowledge of such contexts. Among the possible explanations for these results is that teachers are uninformed regarding indigenous knowledge or everyday experiences relevant to all the learners. The role of the teacher is to guide learners through explaining or demonstrating how learners' different cultural contexts may be used to learn mathematics. However, when teachers are unable to explain contexts well to all the learners, the mathematisation process will be an uphill task for learners as they may be required to learn mathematics in contexts, which they lack knowledge of. In the same vein, Student Teacher B2 asserted the integration of cultural contexts learners do not know could lead to their loss of interest in learning. In this regard, she pointed out that when learners *"become confused because of the context ... [they] … don't know, [they] are likely to lose interest in learning mathematics"* (ST B2, TI, Add H:117). She further stressed that *"cultural backgrounds which are used to help learners learn maths can also exclude other learners"* (ST B2, TI, Add H:117). These perceptions may infer that it is essential for teachers to integrate cultural contexts that learners can relate to in order to minimise the confusion. However, Student Teacher C6 felt this may be a challenge for teachers since "*there are many cultures and will not be easy to accommodate all the learners in the classroom*" (ST C6, PQ, Add I:141).

Furthermore, results revealed that teachers may lack knowledge of other learners' cultural backgrounds, which could be integrated within ethnomathematics contexts. In this regard, Student Teacher B1 believed that

> *when you are not knowledgeable about certain culture, you focus on one culture and leave another out … As an Indian, I could easily emphasise on Indian cultures but African culture I might be lacking … so there will be a problem for African learners in my classroom and they will feel excluded.* (ST B1, TI, Add H:111)

The above quotation from Student Teacher B1 highlights the participant's perception that although teachers are expected to be knowledgeable about utilising learners' cultural contexts, they may not have knowledge of other cultural practices outside their own cultures. Thus, learners who share the same cultural backgrounds with their teachers might benefit, while others may feel excluded in the learning process. Teachers' lack of knowledge of mathematics concepts found in other cultures apart from their own could miss out on the valuable contributions of such cultures towards contextualising mathematics. While teachers are not necessarily cultural experts, a knowledge of mathematics concepts, skills, procedures, and symbols found in various cultures is necessary towards creating a balanced learning environment within a multicultural classroom.

(c) Synthesis of teacher educators’ and student teachers’ findings integrated with literature

What can be learned from participants’ perceptions is that cultural diversity can hinder effective integration of ethnomathematics in the teaching and learning of mathematics. One of the reasons for perceiving cultural diversity as a challenge was mainly attributed to difficulties of accommodating all learners from diverse cultural backgrounds. There are diverse mathematics contexts from diverse cultures that might make it difficult for teachers to identify and select contexts that can accommodate all the learners. Cultural practices, methods, skills, and symbols differ from one cultural group to the other. There are diverse mathematics contexts from diverse cultures that might make it difficult for teachers to identify and select contexts that can accommodate all the learners. The findings confirm earlier assertions that mathematical thinking and methods are quite different in different cultures (Gerdes, 2001; Rosa & Orey, 2010). As a result, it will be a challenge for teachers to accommodate and represent all existing cultures in the classroom.

The findings also showed that the contextual examples that teachers may consider appropriate for contextualising mathematics may create confusion, exclusion, and loss of interest in the learning processes, especially amongst learners who do not have knowledge of the contexts. Where ethnomathematics is used as an instructional approach in such instances, learners may struggle to mathematise on the basis of their lack of knowledge about the cultural contexts serving as a reference point to contextualisation. The findings of this study concur with the findings of the studies conducted by Sunzuma and Maharaj (2020) and Van der Walt et al. (2019), which showed that cultural diversity could negatively affect the integration of ethnomathematics in the teaching and learning of mathematics.

Although cultural diversity is acknowledged as a challenge, it was perceived that it may create a learning environment where learners explain mathematics ideas from their unique cultural viewpoints. By allowing learners from different cultures to share their ideas, teachers are also catering to the diverse cultural backgrounds within the classroom, according to the participants. This finding affirms that teachers need to take measures to ensure a balance of cultural representations in the classroom, as noted by Brandt and Chernoff (2015). In the next theme, I focus on teacher educators and the expert pertaining to curriculum responsiveness as a barrier to effective integration of ethnomathematics.

5.8.2 Theme 2: Teacher educators are of the perception that CAPS curriculum is not responsive towards ethnomathematics

Perceptions from four teacher educators revealed that Mathematics CAPS is not responsive to ethnomathematics. Their perceptions highlight that ethnomathematics is not adequately addressed by this curriculum. One teacher educator mentioned that the *"the CAPS is so full of content and nowhere one word in the content in the examples are referring to indigenous knowledge contextualizing and mathematizing the context*" (TE B2, ES, Add G:58). Among the likely explanations for these results is that the mathematics CAPS do not provide sufficient guidelines or examples towards the integration of ethnomathematics. No examples of learners' cultural backgrounds that can be implemented when contextualising mathematics are included in CAPS.

Similarly, Teacher Educator A3 contended that the CAPS mathematics curriculum is silent "*on the issues of culture in mathematics education"* (TE A3, ES, Add G:53). She further highlighted that the assessments in mathematics are

> *mainly done in an abstract manner with no reference to learners' cultural backgrounds. This creates a major difficulty and has serious implications for initial teacher education programmes. Even our students wouldn't really see a need to integrate ethnomathematics as it is not part of curriculum in terms of what is taught and assessed.* (TE A3, ES, Add G:53)

These results highlight participants' perceptions that learners' cultural contexts are not integrated in both teaching and assessment activities, which means CAPS does not accommodate cultural contexts which learners may relate to. Furthermore, the scarcity of learners' cultural contexts in Mathematics CAPS may have a negative effect on the student teachers as they might ignore such contexts in the teaching-learning environment. Student teachers therefore may base their instructional decisions without integrating ethnomathematics or sociocultural contexts.

In addition, another teacher educator argued that assessment activities often use cultural contexts that some learners are unfamiliar with. In this regard, he demonstrated with an example from a previous mathematics question paper

> *on measurements, and the context that was given there was on parking lots. When I was going through that question, I was worried, to say a learner from Moletjie … can get that question right, just because of the parking lot.* (TE A1, F2F, Add G:22)

The results suggest that using sociocultural contexts that are unknown to some student teachers and learners could create learning barriers. Although many learners might have been unfamiliar with the context of a parking lot and could not solve the problem, this should not be perceived as ethnomathematics but rather an aspect thereof. The role of sociocultural contexts is to make mathematics accessible and meaningful; however, when the contexts become inaccessible it can deepen learners' challenges. Although the examiner and the moderator of the mathematics question paper had been ignorant of different learners' cultural contexts, if teachers teach these kinds of problems in context and introduce the context to learners who are unfamiliar with the context and then mathematise it, it may provide such learners with an opportunity to solve such problems.

The above quotations from Teacher Educators A1, A3, and B2 further illustrate participants' perceptions that Mathematics CAPS (SADBE 2012) is performance oriented. As a result, mathematics teaching does not only accommodate indigenous knowledge from learners' cultural worldviews. Among the probable explications for these findings is that learners are often taught mathematics in an abstract manner without concrete examples or activities from their different cultural contexts. A performance-driven curriculum often relies on a transmission teaching strategy which has no regard for learners' indigenous knowledge or ethnomathematics. In this regard, teachers focus on drilling learners in accordance with examination guidelines. The findings of this study are consistent with Mbusi's (2011) and Naresh's (2015) assertions that teachers focus on drilling learners on rote examination procedures as ethnomathematics is not infused in the examination papers. For example, the mathematics examination questions are not contextualised using cultural contexts. These perceptions further suggest the possibility that student teachers may not realise the valuable benefits of using learners' cultural backgrounds in their prospective classrooms, especially when CAPS is silent on those aspects. What can be inferred from teacher educators' perceptions is that the CAPS curriculum should include learners' cultural backgrounds in both the teaching, learning and assessments. For example, contextualising examination questions in learners' sociocultural contexts such as indigenous games may possibly influence teachers to consider ethnomathematics in the teaching and learning of mathematics.

To take the analysis on the responsiveness of the curriculum a step further, one teacher educator questioned the extent of ethnomathematics in the curriculum. In this regard, he asked:

> *The curriculum, is it taking care of issues of culture in mathematics? Is the ethnomathematics practised in the schools? It has to start from the very same curriculum we are serving…Once the curriculum takes care of that aspect, we will be left with no choice but to be responsive to what is there.* (TE A2, F2F, Add G:30)

He further asserted that the integration of ethnomathematics should not be limited to pre-service teacher education but systematised

> *from grade RR to beyond teacher education programme. It has to talk to the system, from start to finish. We cannot say we are limiting it to teacher education, although with teacher education I think the call will be…on how it informs the classroom practising, the system one, not necessarily teacher education programme.* (TE A2, F2F, Add G:34)

The above quotation from Teacher Educator A2 illustrates the participant's perception that curriculum may need to embrace cultural aspects in the teaching and learning of mathematics in all the phases of schooling. Thus, according to Teacher Educator A2, ethnomathematics should be included in the mathematics curriculum across all school phases. This perception proposes that a focus on ethnomathematics in pre-service teacher education might not yield a desirable outcome if it is not part of the mathematics curriculum. Among the plausible explanations for these results is that when learners' cultural aspects are included in the Mathematics CAPS, then pre-service teacher education will respond to accommodate such aspects in detail in the mathematics education modules. The findings of this study concur with Matang (2008) and Naidoo (2010) in that curriculum developers may have failed to develop a curriculum that integrates IKS aspects that can be used in the classroom.

On the contrary, the expert who served as a mathematics subject advisor and has experience of facilitating teachers' professional development workshops on contextualising mathematics felt strongly that the curriculum is responsive to ethnomathematics. In particular, he expressed that the departmental officials and teachers often highlight that

> *CAPS does not accommodate* [ethnomathematics] *but … it is accommodated. [But] if you look at … the aims of teaching maths which are outlined in CAPS maths …* [it] *… embraces ethnomaths … Some of the specific aims of CAPS…are in line with the ethnomaths … One of the specific aims … says a critical awareness how mathematics relationships are used in a social, environmental, cultural and economic relationship. In other words, as we teach maths, how do we achieve that?* (E 1, TI, Add G:73)

This perception proposes that the aims of mathematics underpin ethnomathematics. However, he further stressed that teachers often do not *"see that … synergy"* between the aims of the mathematics curriculum and ethnomathematics and as a result *"they ignore first pages of CAPS …* [and] … *go straight to content which they have to teach. That's why they will teach the old way"* (E 1, TI, Add G:73).

Based on the expert's perceptions, it can be inferred that the CAPS curriculum advocate for the inclusion of ethnomathematics in the teaching and learning of mathematics. It is further suggested that the introductory sections of the CAPS curriculum not only focus on defining mathematics but on outlining the specific aims of mathematics, which provide a strong basis for integrating ethnomathematics. For example, one of the aims focuses on contextualisation of mathematics through learners' social, cultural, and environmental backgrounds as a focal point of teaching mathematics, as evident in the CAPS curriculum (SADBE, 2011). However, teachers tend to focus on the mathematics content without taking into consideration learners' sociocultural contexts. The perceptions may possibly suggest that teachers are unfamiliar with what cultural aspects one can use to contextualise mathematics topics, and they are unfamiliar with mathematising contextualised topics in mathematics. The expert's perception further suggests such limitations hinder teachers' creativity in contextualising mathematics through ethnomathematics. Hence, mathematics teachers are reluctant to use ethnomathematics in their classrooms (Seroto, 2012).

The expert believed that the implications from a specific aim in the CAPS is that teachers are prepared by teacher training and professional development workshops on contextualising mathematics through using various learners' cultural contexts. As a result, the mathematics aim, as articulated in the CAPS curriculum, may be achieved. While the CAPS mathematics curriculum's specific aims do not specify relevant social and cultural contexts, the expert's contention is probably that teachers have the necessary PCK and skills to identify relevant examples from learners' social and cultural contexts to contextualise mathematics. Among the probable expositions for these findings is that teachers should find relevant information from learners' cultural backgrounds that can be integrated effectively and meaningfully in contextualising mathematics.

5.8.3 Theme 3: Lack of learners' cultural contexts in mathematics textbooks

In this theme, the results from teacher educators, the expert and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' and the expert's interviews, then I discuss the results from student teachers' interviews and focus groups. Finally, I synthesis the findings integrated with literature.

(a) Results from teacher educators and expert

The integration of ethnomathematics does not only depend on student teachers' abilities but also on the availability of ethnomathematics resources. Teachers and learners use textbooks as the main teaching and learning resource. Availability of teaching and learning resources such as textbooks play a significant role in the effective integration of ethnomathematics. Equally important, a lack of resources focusing on ethnomathematics could hinder its effective integration into the teaching and learning of mathematics. In this regard, Teacher Educator B2 asserted that there is a lack "*of quality mathematics textbooks or sources that covers all the diverse context in South Africa focusing on contextualising and mathematising maths"* (TE B2, ES, Add G:57).

Similarly, Teacher Educator A2 emphasised that *"textbooks that are used in schools … are not responsive to ethnomathematics"* (TE A2, F2F, Add G:33). He further underscored that mathematics textbooks focus on presenting mathematics concepts without *"tapping into learners' culture"* and create learning difficulties for the learners. In the same vein, an expert stressed that the textbooks *"explain from a different … social … economic context … which is not familiar to an individual* [learner]" (E 1, TI, Add G:64). Thus, learners often consider mathematics as presented in the textbook as difficult as *"it is not acknowledging* [their] *culture and what they bring in the classroom"* (TE C1, TI, Add G:39) and *"the examples which they are making … are foreign to* [learners]*"* (E 1, TI, Add G:64).

The above quotations from teacher educators and the expert suggest that learners and teachers often struggle to understand mathematics concepts and ideas because of a lack of inclusion of any culture as contexts in textbooks. The results highlight that the mathematics textbooks, which are dominantly used in South African classrooms, do not reflect learners' diverse cultural contexts. While CAPS considers the contextualisation of mathematics through learners' sociocultural contexts, there is a scarcity of such contexts in the teaching and learning resources. The integration of learners' sociocultural contexts in the mathematics textbooks cultural contexts could alleviate learners' difficulties in mathematics.

(b) Results from the student teachers

The trend of lack of textbooks, which integrates ethnomathematics was also strengthened by four student teacher participants. They strongly believed that the mathematics textbooks do not integrate contexts from learners' different cultures. For example, Student Teacher A2 noted that the prescribed textbooks *"do not really add issues of cultural backgrounds. That will be a challenge for learners because they learn mathematics using these textbooks"* (ST A2, FG, Add H:89). Similarly, Student Teacher A4 felt that textbooks put more emphasis "*on procedures than contexts from learners' culture"* (ST A4, FG, Add H:89) and *"the concepts are explained in an abstract [approach]"* (ST B2, TI, Add H:117). These perceptions propose that mathematics textbooks are more procedural than contextual. Thus, according to the student teacher participants, mathematics concepts are first presented and explained in an abstract approach followed by a step-by-step procedure related to carrying out mathematics activities related to such concepts. The results suggest a scarcity of context-based mathematics learning activities based on learners' cultural contexts. The mathematics textbooks, which are CAPS aligned appear to deny learners opportunities to learn mathematics from their own or others' culture(s).

(c) Synthesis of teacher educators', expert's, and student teachers' findings integrated with literature

What can be seen from the four teacher educators', one expert's, and four student teachers' findings is that there is a common agreement that a lack of contextualised curriculum resources may hinder effective integration of ethnomathematics in the teaching and learning of mathematics. Although the CAPS mathematics curriculum's specific aims advocate for the inclusion of cultural contexts (SADBE, 2011), the mathematics resources such as learners' and teachers' textbooks are silent on learners' cultural contexts, according to the participants. The teaching and learning resources often use contexts that may not relate to learners' cultural backgrounds. Thus, according to the participants, ethnomathematics contexts are not integrated into the mathematics textbooks. Although the participants reveal a scarcity of learners' cultural contexts in mathematics textbooks, it may be a challenging task to accommodate all the various culture contexts due to the issues related to the cultural diversity in South Africa, as discussed previously. The findings further propose that when the curriculum resources such as textbooks do not address ethnomathematics contexts sufficiently, teachers may ignore them in the teaching. A lack of curriculum resources based on learners' social, cultural, and environmental backgrounds might limit the possibility of integrating ethnomathematics in the mathematics classroom (Sunzuma, 2019; Sunzuma & Maharaj, 2020). As a result, teachers who depend mainly on the textbooks may not integrate ethnomathematics in their classrooms.

As evident from teacher educators, the expert, and student teachers, the textbooks are based on abstract mathematics with no focus on examples from culture. The findings further infer that the textbooks present mathematics as a culture-free subject, subsequently promoting the traditional philosophical orientation as discussed in the literature review chapter. The findings concur with earlier findings by Madusise (2020) and Sunzuma (2019) that the textbooks and other curricular materials have given little attention to learners' cultural contexts in the teaching and learning of mathematics. The findings further strengthen Seroto's (2012) recommendation on the need to develop ethnomathematics teaching and learning resources that could be used for the purposes of teaching and learning. The findings also provide evidence that mathematics education researchers in ethnomathematics need to compile a textbook(s) with all possible different cultural aspects included - as a resource for teachers.

5.8.4 Theme 4: Lack of ethnomathematics integration and discouragement of student teachers by mentor teachers towards integrating ethnomathematics during work-integrated learning

In this theme, the results from teacher educators, the expert, and student teachers are presented and interpreted. Firstly, I focus on the results from teacher educators' and the expert's interviews before focussing on the results from student teachers' interviews and focus groups. Finally, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators and the expert

Work-integrated learning (WIL) plays an integral role in student teachers' professional development as prospective teachers and provides opportunities for student teachers to put into practice theoretical knowledge gained in pre-service mathematics education programmes (Hill, 2021; Mentz & De Beer, 2020; Singh & Singh, 2012). During WIL, the student teachers are often supervised by mentor teachers who provide pedagogical support, amongst others. However, the results revealed that mentor teachers discourage student teachers from integrating ethnomathematics during WIL. In this regard, Expert 1 emphasised that when student teachers

> *go to teaching practice, they come back being so demotivated, saying, it's like what we are taught here* [at the university] *… as we go* [to] *schools that's not supposed to be done because … they will tell you that the exam is designed in this way*. (E1, TI, Add G:72).

The aforementioned quotations from the expert highlight the participants' perceptions that one of the reasons student teachers are discouraged from using ethnomathematics may be that the CAPS curriculum is performance driven. The contention is that the performance-driven curriculum may promote a drill and memorisation learning environment with little emphasis on context-based learning. This was also evident in Teacher Educator B2's perception that "*students are discouraged to use ethnomathematical practices in school"* as a result of *"a performance-based system, and … overload[ed] CAPS curriculum content"* (TE B2, ES, Add G:58). These perceptions suggest that teachers may base their instructional decisions on covering mathematics concepts as presented in the curriculum abstractly. As a result, student teachers from University B who are exposed to ethnomathematics in their pre-service mathematics education are discouraged from using it during their WIL experiences. These perceptions propose that student teachers who are trained in ethnomathematics during pre-service mathematics education may not have freedom of choice in terms of integrating ethnomathematics pedagogical knowledge and skills acquired in mathematics education modules. The results imply a lack of pedagogical support for student teachers to integrate ethnomathematics in their classrooms during WIL. As a result, student teachers might feel demotivated by a teaching environment, which limits them to a certain instruction approach, disregarding ethnomathematics. These perceptions further imply that mentor teachers do not integrate ethnomathematics in their mathematics classrooms, as they rely on transmission mode teaching strategies, which drill learners in accordance with examination guidelines.

Furthermore, another teacher educator participant observed a lack of ethnomathematics in student teachers' mathematics classrooms: "*When we go out for teaching practice, we do not see it. We still see them* [student teachers] *still teaching the way they were taught*" (TE A2, F2F, Add G:29).

The above-mentioned observation from Teacher Educator A2 illustrates the participant's perception that student teachers do not integrate ethnomathematics during WIL. One possible reason for a lack of integration of ethnomathematics particularly by University A student teachers during WIL is that they are not trained in ethnomathematics, as revealed earlier. The results further infer that student teachers emulate their mentor teachers' instructional strategies that do not accommodate ethnomathematics.

(b) Results from student teachers

The results from the student teachers also revealed that the mentor teachers do not contextualise mathematics through ethnomathematics. In this regard, Student Teacher B2 stated that at the school she was conducting WIL lesson "*observations … [mentor teachers] are not using it* [ethnomathematics] … *Teachers just take curriculum [textbook] as it is, and they present it to learners"* (ST B2, TI, Add H:118) and as a result teachers *"won't be able to really focus on … learners' culture[s]"* (ST A1, FG, Add H:89). The results suggest that mentor teachers' discouragement towards student teachers integrating ethnomathematics is probably attributed to the dependency on textbooks, which do not include learners' sociocultural contexts. Among the possible explanations for these results is that mentor teachers often base their instructional decisions as per step-by-approaches that are found in many mathematics textbooks. In such instances, as argued by Student Teacher A1, the teachers will likely not utilise learners' cultural contexts in the teaching and learning of mathematics.

Furthermore, the results revealed that scarcity of ethnomathematics in mentor teachers' instruction decisions may be attributed to resistance to embrace pedagogical changes. In this regard, Student Teacher A2 argued that the *"problem is that they* [mentor teachers] *did not want to evolve with time*" (ST A2, FG, Add H:88). Similarly, Student Teacher A3 felt strongly that mentor teachers "*chose to just ignore the* [pedagogical] *changes [and] that is why they are still teaching* *the same way they taught 15 years ago"* (ST A3, FG, Add H:88). These perceptions propose that mentor teachers rely on past pedagogical practices that do not embrace the role of learners' sociocultural contexts in contextualising mathematics. The results suggest when mentor teachers embrace the pedagogical changes, they may not discourage student teachers from integrating ethnomathematics.

(c) Synthesis of teacher educators', the expert's, and student teachers' findings integrated with literature

What can be seen from teacher educators', the expert's, and student teachers' results is that the mentor teachers, during WIL, do not offer student teachers opportunities to put into practice ethnomathematical perspectives learnt in theoretical modules. The student teachers, from the expert's and teacher educator's perceptions, are encouraged to teach mathematics in accordance with examination guidelines. The contention is that the manner in which examinations are set, do not accommodate social and cultural contexts but rather are abstract in manner. These perceptions may also imply a possibility that mentor teachers are not familiar with ethnomathematics contexts that link with mathematics, as they may not have been taught ethnomathematics in pre-service mathematics education and/or through professional development by the DBE. Their classrooms are characterised by traditional teaching strategies that do not consider learners' cultural practices as an entry point to their learning. The findings of the current study concur with researchers such as Naresh (2015) and Rosa and Gavarrete (2017) who underscored that many teachers believe that there is no place for ethnomathematical perspectives in their mathematics classroom. Among the possible explanations for these findings is that the national available textbooks do not present any examples or resources based on ethnomathematics contexts.

Furthermore, the findings suggest the discouragement towards using ethnomathematics by the mentor teacher might result in a tension between what student teachers learn in theory and what happens in the classroom. The findings further strengthen earlier assertions by Gravett et al. (2014) and Roth et al. (2014) that the theory learnt as part of pre-service teacher education programmes is largely divorced from the reality of student teacher experience in the classrooms. As a result, student teachers in these instances may find themselves having to teach mathematics using the transmission-mode teaching strategies that do not include learners' cultural backgrounds, as pointed out by Teacher Educator A2, quoted above.

In the next theme, I focus on technology approaches as a barrier to effective integration of ethnomathematics.

5.8.5 Theme 5: Technological approaches may hinder integration of ethnomathematics into the teaching and learning of mathematics

In this theme, the results from teacher educators and student teachers are presented and interpreted. Firstly, the results from teacher educators' interviews are considered, then I focus on the results from student teachers' interviews and focus groups. Finally, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators

The use of technology approaches in the teaching and learning of mathematics has central influence in the 21st century educational landscape. Technological advancements might not only create new teaching and learning environments but pose a challenge to other innovative culturally responsive teaching pedagogies such as ethnomathematics and indigenous knowledge systems (Hidayat et al., 2020; Utete et al., 2019). In this regard, two teacher educators from University A perceived technology pedagogies as a challenge to ethnomathematics. For example, one teacher educator explained that

> *21st century learning environments are characterised by growing technological pedagogies which has great impact and implications in the mathematics classroom. The focus is on preparing our students towards meeting the demands of 4th Industrial Revolution in their mathematics classrooms.* (TE A3, ES, Add G:53)

In addition, Teacher Educator A2 underlined that in *"the era we find ourselves in, the move is towards preparing our student teachers to take care of aspects of technology in their own classrooms"* (TE A2, F2F, Add G:34). The emphasis is that the integration of *"indigenous knowledge in mathematics classrooms dominated by technologically active learners would likely be a challenge to them"* (TE A3, ES, Add G:53).

The above quotations from Teacher Educators A2 and A3 highlight the participants' perception that the student teachers are equipped with pedagogical knowledge-related technology approaches. The results suggest that student teachers should be able to adapt and teach mathematics through using technology-based instructional approaches. Among the possible expositions for these results is that the 21st century classrooms consist of learners that are technologically active with a variety of technology resources at their disposal. These results propose that learners may spend more time on technology-based activities than on activities found in their cultural practices (Chahine et al., 2013). As a result, integrating cultural resources drawn from learners' cultural backgrounds might be considered irrelevant within contexts of technology-equipped classrooms, according to the participants. The teacher educator acknowledged that student teachers might encounter challenges with regard to integrating indigenous knowledge which constitutes ethnomathematics. The challenge could be on the basis that learners might be passive within ethnomathematics approaches as they spend more time on technology than on indigenous knowledge resources.

(b) Results from student teachers

The results from the student teachers also revealed that technology developments can pose a challenge to ethnomathematics approaches. In this regard, student teachers noted several challenges regarding the place of ethnomathematics in the classrooms equipped with technology resources. For example, one student teacher pointed out that *"most of the schools are moving in the direction of 4th industrial revolution. Schools out there are equipped with smartboard; learners use tablets and other technology devices are used to teach mathematics.*" (ST A1, FG, Add H:88). The contention is that *"the use of technology has increased so much"* (ST B2, TI, Add H:117) and as a result, *"attention is given to technology resources [rather] than cultural resources in schools"* (ST B3, ES, Add H:122). The results provide evidence that more effort is dedicated towards technology than ethnomathematics resources. Furthermore, Student Teacher A4 felt strongly that the changes linked to technology suggest

> *if you are going to use what was there before, it might not be what the new generation know so it means you have to familiarise yourself with certain concepts so that you can use them appropriately in the classroom.* (ST A4, FG, Add H:88)

The above assertions from Student Teachers A1, A4, B2, and B3 are consistent with Teacher Educator A3's perception in that they also highlight the implications of the pedagogical shift imposed by technology advancement. In this regard, they stressed that not only classrooms are equipped with technology resources but also learners are knowledgeable about various technology resources that can be used as learning resources. For student teachers, learners' familiarity with technology resources could suggest a lack of focus on resources found in cultural contexts. Among the probable explanations for these results is that the current generation of learners might not know some of the cultural practices or resources that existed in the past generations. Under such circumstances, it will be a challenge for learners to learn mathematics resources from cultural backgrounds, according to the participants. The integration of ethnomathematics, which relies on cultural resources could be a challenge to learners who are familiar with technology. The results provide evidence that the integration of ethnomathematics in a technology-driven learning environment might be considered as backward and irrelevant for learners. The results also suggest that student teachers are unfamiliar (a lack of knowledge of what is available) with the content (cultural practices as well as ethnomathematics) available on the internet.

To take the analysis a step further, another student teacher emphasised that *"the new development on technology makes everything required simple … compared to all those indigenous ways of teaching. Like for an example, let's take those apps that can solve mathematics equation and expressions"* (ST C7, FG, Add H:106). This suggests that technology approaches and resources provide a more sophisticated learning environment where abstract mathematics concepts can be solved. In other words, technology resources provide opportunities for learners to solve mathematics problems, which are generally not solved through cultural resources. Among the possible explications for these results is that the technology-based learning environment enables learners to compute mathematics concepts, while ethnomathematics is limited in such an aspect. She further stated that

> *even if as a teacher you can use those indigenous or ethnomathematics approaches, but if learners are well knowledgeable about the apps or new technology developments obviously they would end up going for the new developments of technology or those apps.* (ST C7, FG, Add H:106)

While the teachers might consider integrating ethnomathematics into the teaching and learning of mathematics, learners' preferences will likely be towards technology resources. The contention is that learners will find it easier to learn through technology resources than cultural artefacts.

On the other hand, Student Teacher C3 pointed out that she does not consider

> *technology could cause problem for the use of ethnomathematics in our classroom settings … one challenge that may arise from trying to use … these technological resources and … ethnomathematics into your teaching … I feel like they might struggle to connect the two…Real challenge here would be the teacher's ability to integrate both ethnomathematics and technological resources.* (ST C3, FG, Add H:105)

The aforementioned quotation from Student Teacher C3 highlights the participant's perception that technology and ethnomathematics may be amalgamated into the teaching and learning of mathematics. The perception further indicates that the amalgamation of the two approaches depends on the teacher's ability. The student teacher suggest that ethnomathematics and technology are two completely different approaches, which consist of different resources; and, as a result, teachers may struggle to amalgamate the two approaches in their instructional decisions. The suggestion is that teachers should have knowledge and skills to utilise the two approaches together. The results provide evidence that technology and ethnomathematics approaches are not competitive pedagogies but rather complementary, as pointed out by Student Teacher C3, quoted above.

Similarly, Student Teacher C4 suggested a possible solution towards amalgamating technology and ethnomathematics. He pointed out the "*software developers [should] develop [Morabaraba] games* … *[and]* … *relate them to that software … we will see how technology is advancing the ethnomathematics within the classroom"* (ST C1, FG, Add H:104-105). This quotation illustrate the student teacher's perception that the digitalisation of indigenous games could advance ethnomathematics. Among the plausible explications for these results is that the integration of ethnomathematics within the technology-driven learning environment may become possible when cultural artefacts are integrated in technology resources. Under such circumstances, technology would not hinder integration of ethnomathematics but promote it.

Furthermore, two student teachers also revealed that technology resources such as computers and the internet can be used to explore how cultural practices may be integrated to teach mathematics. For example, Student Teacher B1 stated:

> *We often think of a computer to be Eurocentric…but it can also be used to explore cultures… We can use technology to research…how to incorporate culture in mathematics. We can get more information on that, and it can be used as a tool to advance [ethnomathematics]*. (ST B1, TI, Add H:111-112).

Along the same line, another student teacher suggested "*if you don't understand [certain] culture[s], you can basically … google it and that way you will have better understanding of what cultural backgrounds to use in your teaching*" (ST B2, TI, Add H:117).

These perceptions suggest that the internet is a great resource of indigenous knowledge, where even examples of ethnomathematics are available. The results provide evidence that technology can be used as a valuable platform for teachers to explore how mathematics can be contextualised through cultural contexts. Among the plausible explanations for these results is that both teachers and learners might not have access to cultural artefacts in real life, but they might get a better idea about their cultural artefacts by finding videos or games or examples on the internet. These results highlight a combination of technology and culture, which crosses the limitation of not having access to cultural artefacts in real life (in the school or at home).

Furthermore, Student Teacher C4 emphasised that a lack of technology resources could promote the integration of ethnomathematics in the classrooms. She pointed out that, *"If we take into consideration not everyone has access to the technology that is being used and when we use ethnomathematics is also very simple to create the stuff yourself*" (ST C4, FG, Add H:105). The results provide evidence that there is a lack of technology resources in schools. As a matter of fact, teachers and learners might not have access to technology resources in their school, which might provide opportunities for them to use culturally-based resources from their everyday contexts. The student teacher seems to be aware of the lack of computers and access to the internet at most South African schools. There are only a few schools—mostly private schools—where there are sufficient computers and access to internet available. The student teacher's perception is that the availability of ethnomathematics resources, which can be found in different cultural backgrounds creates a greater possibility of integrating ethnomathematics. The results provide evidence that ethnomathematics resources can be created without any cost related and as such makes it easier to contextualise mathematics through learners' cultural backgrounds.

(c) Synthesis of teacher educators' and student teachers' findings integrated with literature

What can be inferred from the participants' findings is that the advances in technology may hinder successful integration of ethnomathematics in mathematics classrooms. The technology-based teaching approaches are noted as a threat to ethnomathematics in the teaching and learning of mathematics. The findings provide evidence that the 21^{st} century classrooms are characterised by learners who are actively engaged in using technological resources. Among the probable expositions for these findings is that learners may not be familiar with indigenous practices from the past generations, as pointed out by Student Teacher A4, quoted above. Learners may not have knowledge about ethnomathematics artefacts as compared to technology resources. For example, learners spend more time on technology devices such as various apps on smartphones. Thus, ethnomathematics may not be relevant to learners who are more apt in technology resources.

The findings also revealed that technological instructions are dominant in many mathematics classrooms. Among the possible explanations for these findings is that more emphasis will be given to technological resources than ethnomathematics, which relies on resources from learners' cultural contexts. It was evident that technology pedagogies could make the teaching and learning of mathematics simpler and quicker as it takes less time compared to ethnomathematics pedagogies. The findings of this study concur with an earlier finding by Chahine et al. (2013) that the resistance to incorporate ethnomathematical perspectives may be attributed to the preconceived belief related to the nature of ethnomathematics as being backward and pushed away from technological progress.

While the study conducted by Hidayat et al. (2020) argued that technological advancement makes culture more forgotten, the findings of this study revealed that technology and ethnomathematics may be amalgamated into the teaching and learning of mathematics. However, the findings also suggested that teachers' abilities to amalgamate the two approaches may be a limiting factor, as noted by Student Teacher 3, quoted above. Among the plausible explanations for these findings is the software developers may develop software based on ethnomathematics contexts such as indigenous games. The findings suggest that when ethnomathematics contexts are infused or embedded with technology, the two pedagogical tools may become integrated. The finding is consistent with Kurniawan et al.'s (2021) argument that ethnomathematics can be integrated with technological pedagogies to promote a problem-based learning approach.

The findings of the current study further revealed that a lack of access to technology in most schools, in particular rural schools, in South Africa may provide teachers with opportunities to explore the possibilities of integrating ethnomathematics. Among the plausible elucidations for these findings is that cultural artefacts such as indigenous games are based on teachers' and learners' sociocultural practices from their everyday life, consequently they may create such resources. The present findings also suggest that technology resources may not be readily available in disadvantaged schools as compared to ethnomathematics, which may be found in learners' environments. The finding is consistent with assertions of a past study by Dube (2020), which highlighted that in South Africa, online learning excludes many rural learners from teaching and learning, due to a lack of resources to connect to the internet and low-tech software. The findings provide evidence that a lack of technology resources may provide opportunities for ethnomathematics to permeate mathematics classrooms**.**

5.8.6 Theme 6: The integration of ethnomathematics approaches in the teaching and learning of mathematics is perceived as time-consuming

In this theme, the results from teacher educators, the expert, and student teachers are presented and interpreted. The results from teacher educators and expert interviews are presented first, followed by the results from student teachers' interviews and focus groups. Lastly, I focus on the synthesis of the findings integrated with literature.

(a) Results from teacher educators and the expert

The results from the teacher educators and the expert revealed that time constraints limit the possibilities of integrating ethnomathematics into the teaching and learning of mathematics. In this regard, Teacher Educator A3 stressed that contextual teaching

> *requires a lot of teaching time. Teaching time is likely to be lost while focusing on contexts rather than mathematics content you intend to teach… You may find instances where*

> *learners in the classroom tend to focus on the context rather than the mathematics you would want them to learn.* (TE A3, ES, Add G:52)

Similarly, Teacher Educator B1 also agreed that *"Ethno-mathematics approaches require a lot of planning and teaching time."* She further emphasised that *"some ethno-mathematics activities such as indigenous games learners may spend more time playing than identifying mathematics"* (TE B1, ES, Add G:48).

The above quotations from Teacher Educators A3 and B1 highlight the participants' perception that the integration of ethnomathematics could result in learners paying more attention to the cultural context than the mathematics concepts intended to be learned. In this instance, learners could fail to identify the transition from playing to learning. The main aim of integrating ethnomathematics is for both teachers and learners to "*blend the context and the* [mathematics] *questions*" (TE A2, F2F, Add G:26). Thus, learners may find that the cultural contexts that teachers intend to apply in the teaching environment are more about playing than learning. The results suggest that learners may focus on the fun part related to the cultural context instead of using such contexts as a learning resource. Moreover, the results provide evidence that learners might miss the opportunities of learning mathematics concepts situated within sociocultural contexts that teachers use as a point of reference.

Furthermore, Teacher Educator B2 underscored that ethnomathematics "*consumes a lot of time because it is a new thing, it is not something that can give you one solution, one content that will give you all the maths concept (s) or procedure (s)"* (TE B2, ES, Add G:57). As a result, teachers neglect ethnomathematics as "*they are just concerned with the procedural understanding which is good but … the deeper understanding is very key of which it's like it is disturbing … one to finish the curriculum in schools"* (E1, TI, Add G:72). These perceptions suggest that ethnomathematics, which is a relatively new approach in South Africa, is more concerned with conceptual than procedural understanding. This is mainly because ethnomathematics is not restricted to one-answer solutions as is often the case with traditional philosophical orientation instructions such as drill, memorisation, and practice, characterised by fixed procedures (Ernest, 2009). The result suggests that ethnomathematics does not limit learners to set procedures that they need to follow but rather empowers their mathematisation skills. As a result, teachers and learners may require more time to engage in ethnomathematics-based mathematics problems drawn from sociocultural contexts rather than context-free mathematics activities. Among the possible explanations for these results is that learners may spend a considerable amount of time trying to extract mathematics concepts from sociocultural contexts, which will hinder teachers from covering the curriculum.

(b) Results from student teachers

The results from the student teachers, particularly those who attended the ethnomathematics workshop, also revealed that the integration of ethnomathematics artefacts such as the Morabaraba indigenous game into the teaching and learning of mathematics is time-consuming. In this regard, Student Teacher C1 highlighted that some learners *"don't even know what these games are or how they can use them …. the teacher will spend much time trying to explain the game than teaching [mathematics concepts]"* (ST C1, FG, Add H:100). Along the same line, Student Teacher C4 also emphasised that *"we might have to end up teaching the game and not the lesson"* (ST C4, FG, Add H:101).

The above-mentioned assertions from Student Teachers C1 and C4 highlight the participants' perception that the teacher may shift from teaching the mathematics concepts to teaching sociocultural contexts such as indigenous games, especially in situations where learners are not familiar with the games. These perceptions suggest that learners might not be able to relate the sociocultural contexts to the mathematics concepts. Among the plausible explanation for these results is that teachers may focus on the contexts rather than the mathematics concepts linked with such contexts, which, in the view of student teachers, will consume a lot of teaching and learning time.

Furthermore, another student teacher underlined that *"teacher[s] will need more time to plan the lesson on how to use the game*" (ST C2, FG, Add H:100). This perception suggests that the integration of ethnomathematics goes beyond just the integration of particular cultural contexts but requires planning on how such contexts will be used to explain mathematics concepts. In other words, teachers may take more time looking for teaching-learning and assessment activities, which are essential for the integration of ethnomathematics. The results provide evidence that detailed lesson planning is required for the integration of ethnomathematics and that could take lot of planning and implementation time.

While another student teacher supports time-constraints as challenges to ethnomathematics, she believed that teachers should try to find ways through which they can circumvent the loss of time, as evident in the following comment:

> *the amount of time you would spent initially when you have to introduce the game*. *But I think you also need to understand that this is not the only game, then you can try and find the game that the learners know how to play, go outside during the break, and see what learners are playing and bring that into the classroom. Then you can circumvent the issue*

> *of wasting time trying to teach them how to play that specific game.* (ST C3, FG, Add H:100)

The above quotation from Student Teacher C3 demonstrates the participant's perception that teachers should pay attention to sociocultural activities that learners engage in outside the classroom. By so doing, they may be able to identify contexts, which are familiar to learners. In such instances, it will not necessarily require teachers to spend more time explaining instead of teaching through the cultural contexts. Thus, teachers should implement various ways of managing teaching and learning time appropriately in the context of ethnomathematics perspectives.

Furthermore, the results also revealed that more time may be lost as teachers deal with disruptive behaviour linked to the integration of ethnomathematics. In this regard, Student Teacher C8 emphasised that "*learners could be disruptive when you incorporate games in the classroom*" (ST C8, FG, Add H:101). Similarly, another student teacher also raised concern about "*disruptive behaviour, especially when you are teaching … the large group of learners*" (ST C9, FG, Add H:101). These quotations illustrate Student Teacher C8 and C9's perceptions that disruptions may happen as learners focus on the excitement associated with playing the indigenous games. Among the possible explanations for these results is that sociocultural contexts teachers may consider in their classrooms could result in promoting disruptions, especially in overcrowded classrooms, which may affect the teaching and learning time, according to the participants. However, Student Teacher C3 argued:

> *learners becoming disruptive, yes, the approach that you use might be easier for learners to lose focus and switch to something else, but I think as the teacher, when you are planning out your lesson, you know what kind of learners you are going to teach, you know how they will respond to certain things, and it all comes down to how you manage the class. So, you need to plan yourself, we cannot always just say I won't introduce this now because this class is disruptive and loudly.* (ST C3, FG, Add H:102)

The above quotation from Student Teacher C3 illustrates the participant's perception that regardless of possible disruptions, it remains the responsibility of the teacher to manage classrooms. In other words, the student teacher participant strongly believes that the teachers' abilities to manage classrooms may alleviate disruptions and manage time in the context of ethnomathematics artefacts being integrated in the lesson. Among the plausible expositions for these results is that the benefits linked to ethnomathematics outweigh disruptive challenges, according to Student Teacher C3, quoted above.

(c) Synthesis of teacher educators', expert's, and student teachers' findings integrated with literature

What can be learned from participants' findings is that ethnomathematics may be considered as a time-consuming teaching approach. The findings revealed that teacher educators, the expert, and student teachers believed that ethnomathematics requires a lot of teaching and learning time. The contention is that the integration of ethnomathematics may result in the loss of time as both teachers and learners might focus on the contexts rather than mathematics content. One of the possible explanations for these findings is that more time is required in planning and implementing an ethnomathematics-based lesson than in traditional teaching approaches. The findings of the current study concur with findings of the previous studies conducted by Mbusi (2011), Naresh (2015) and Sunzuma (2019) concerning time as one of the factors hindering the effective integration of ethnomathematics or indigenous knowledge in the classroom.

The findings also revealed that some of the possible reasons attributed to ethnomathematics as time-consuming may be a focus on teaching learners how to play the morabaraba game instead of mathematics concepts, as noted by Student Teacher C4 in the above comments. Participants believed that learners might focus of the fun part of playing the game or discussing the cultural practices rather than mathematics in such contexts. Among the probable explanations for these findings is a possibility that learners might miss the essential mathematics concepts to be learnt while focusing on the fun part associated with the cultural contexts the teacher chooses to use. The findings of the current study are in lines with earlier literature (Metz, 2013) that critiqued learners may focus on contextual aspects of a problem embedded in the context rather than on the salient mathematical concepts.

The findings, particularly from student teachers who attended the workshop, further revealed that it is important for teachers to pay attention to the kind of activities or games learners may engage on during breaks. Among the likely explanations for these findings is that teachers will be exposed to observing and identifying what kind of cultural games learners are familiar with and integrate such games in the classrooms. The findings of the current study support Nkopodi and Mosimege' (2009) argument that time management should be addressed alongside the general matters of teaching strategies that teachers consider.

5.8.7 Summary of the sub-section

To sum up, this section of the study explored challenges that could hinder effective integration of ethnomathematics into the teaching and learning of mathematics. The findings of this study revealed the following challenges may hinder effective integration of ethnomathematics in the teaching and learning of mathematics: The CAPS mathematics curriculum (SADBE, 2011) is not responsive towards ethnomathematics; lack of learners' cultural contexts in mathematics textbooks; lack of ethnomathematics integration and discouragement of student teachers by mentor teachers towards integrating ethnomathematics during teaching practice; cultural diversity; technology approaches; and time constraints.

5.9 SECOND STAGE ANALYSIS BASED ON CULTURAL HISTORICAL ACTIVITY THEORY

In this section, data from the previous section is analysed from a CHAT perspective. As earlier mentioned, CHAT is employed at an interpersonal level, particularly at an instructional level, to analyse the affordances of ethnomathematics in pre-service mathematics education at selected universities. In this regard, Engstrom's (2009) third-generation CHAT is applied to juxtapose two inter-related activity systems, as mentioned previously. In one activity system, the teacher educators are considered as the subject and in the other juxtaposed activity system the student teachers are the subject. From the analysis of the three selected universities (Universities A, B, & C), two sets of activity systems are distinguished. In one set of activity systems, the object is to contextualise the mathematics topics without ethnomathematics, and in the other set with ethnomathematics. Thus, teaching (teacher educators) or learning (student teachers) mathematics with or without ethnomathematics are considered as different sets of activity systems. However, it is important to mention that University C forms part of both two sets of activity systems. This is particularly attributed to the fact that the ethnomathematics intervention was only conducted in University C, and the data obtained prior to the intervention share "similar patterns that emerged from [University A] data" (Sebotsa, 2020, p. 299). In the same vein, in the other set of activity systems, data obtained post-intervention is similar to University B, hence a general activity system is compiled. Herein, I considered it necessary to demonstrate the teacher educators' teaching and student teachers' learning as activity systems relate to and influence each other, as suggested by De Beer (2020), Havenga (2019) and Lazarou (2011). The following two sets of activity systems are analysed:

- **First set of activity systems (Figure 5-2): Activity system 1 and Activity system 3: Contextualisation of mathematics topics without ethnomathematics**

In these juxtaposed activity systems, the focus is on teacher educators contextualising mathematics without using or integrating ethnomathematics in pre-service mathematics education modules. Teacher educators teach the modules without any reference to ethnomathematics. Activity system 3, which is a mirror-reflection of activity system 1, focuses on student teachers learning contextualisation of mathematics without ethnomathematics.

- **Second set of activity systems (Figure 5-3): Activity System 2 and Activity system 4: Contextualisation of mathematics topics through ethnomathematics**

In these juxtaposed activity systems, the focus is on teacher educators contextualising mathematics topics by integrating ethnomathematics in pre-service mathematics education. In this regard, teacher educators use cultural artefacts to demonstrate how mathematics topics can be contextualised. Activity system 4, which is a mirror-reflection of activity system 2 focuses on student teachers learning contextualisation of mathematics topics through ethnomathematics.

These two sets of activity systems are analysed and discussed as follows:

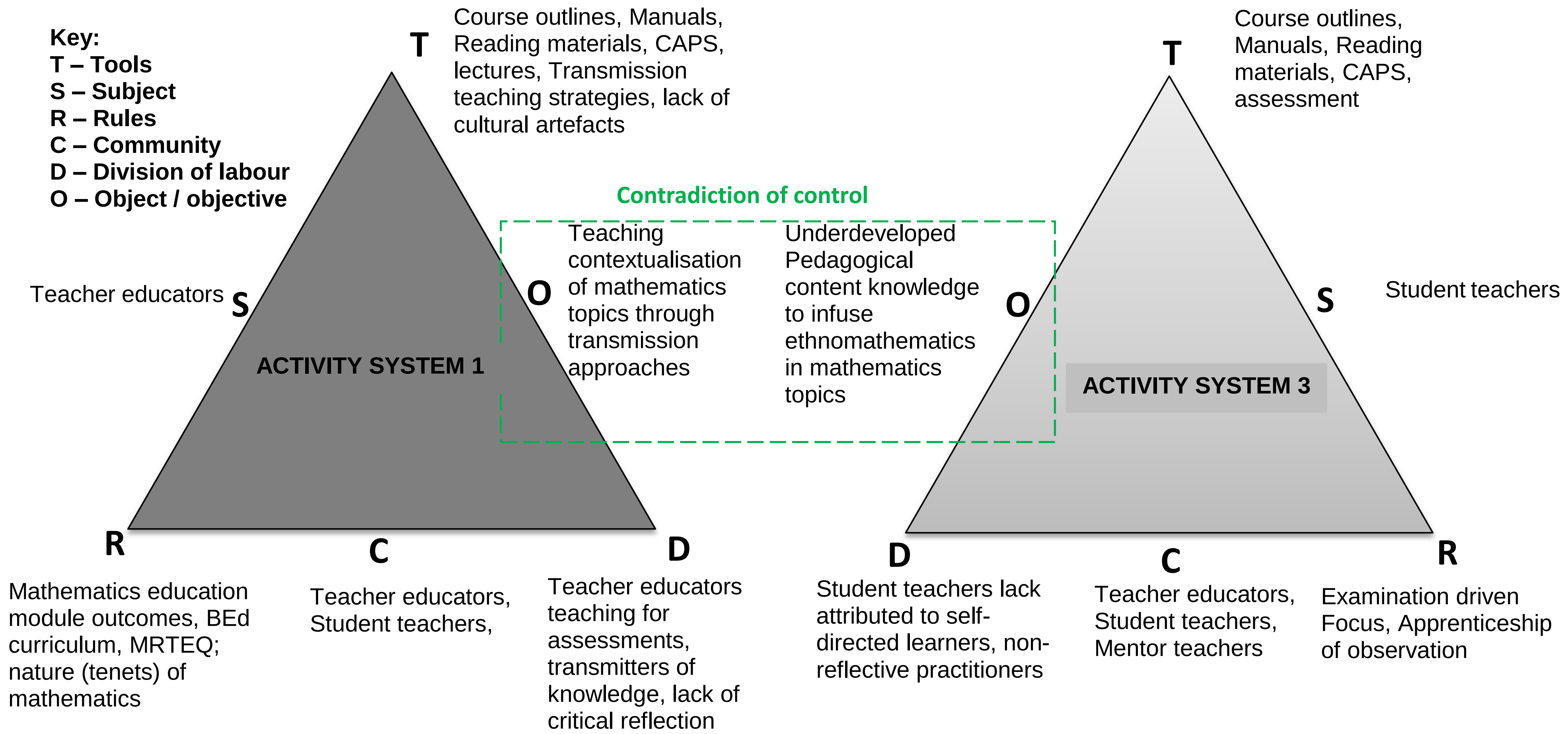


Figure 5-2: Third-generation CHAT employed at instructional level.

(Adapted from De Beer & Mentz, 2017; Havenga, 2019)

As shown in Figure 5-2, Activity **System 1** focuses on teacher educators' facilitation of contextualisation without integrating ethnomathematics in pre-service mathematics teacher education at University A and University C. In this activity system, the object **(O)** as perceived from the teacher educators (**S**) is to equip student teachers with contextualisation of mathematics without ethnomathematics perspectives. Although there is an acknowledgement of the importance of ethnomathematics and need to prepare student teachers in ethnomathematics, it was shown that teacher educators do not use ethnomathematics (cultural) artefacts and learning resources (course manuals and reading materials) as mediating tools (**T**). For example, Teacher Educator A1 stressed that: *"I'm not using any ethnomathematics in the teaching of my method subjects"* (TE A1, F2F, Add G:17). A reason attributed to this is that the focus is on equipping student teachers with technology pedagogical content knowledge. Similarly, another teacher educator participant at University C also pointed out that they are not preparing student teachers in ethnomathematics:

> *Unfortunately, what I have noticed as a lecturer, as a teacher trainer, as a teacher myself is that what we do and what we say is different. Because if we want the student teachers or teachers to use the context to use the culture in their teaching, we need to do so as well. We as the lecturers of the teachers or teacher development people*. (TE C1, TI, Add G:39-40)

In this activity system, the prospects of equipping student teachers with ethnomathematics approaches appear practically impossible due to the transmission teaching approaches. In this regard, the transmission teaching approaches can be viewed as a better way of equipping student teachers on contextualisation. Although CAPS mathematics policy documents as part of mediating tools (T) advocate inclusion of learners' cultural contexts in contextualising mathematics topics, teacher educators felt that CAPS is not responsive to ethnomathematics. For example, Teacher Educator A2 questioned if CAPS is

> *taking care of issues of culture in mathematics? Is the ethnomathematics practiced in the schools? It has to start from the very same curriculum we are serving… Once curriculum take care of that aspect, we will be left with no choice but to be responsive to what is there.* (TE A2, F2F, Add G:30)

Subsequently, there is no need to integrate ethnomathematics in pre-service mathematics teacher education modules. The findings provide evidence that teacher educators are not preparing student teachers in line with the CAPS mathematics curriculum's specific aim of contextualising mathematics through learners' social and cultural backgrounds. As a result, there is evidence of a tension between the tools and the object in this activity system.

Furthermore, there is evidence of tension between the rules and the object in this activity system. Although the nature (tenets) of mathematics (R) highlights the contribution of human cultures in the development of mathematics, there is a lack of evidence of preparing student teachers to contextualise mathematics using cultural contexts. Moreover, MRTEQ makes provisions for teacher educators to develop student teachers' pedagogical content knowledge required to teach mathematics; innovative pedagogies such as ethnomathematics, which have been found to be effective, are often ignored. In this regard, rules (**R**) such as module outcomes and learning guides in University A and University C prevent the outcome (**O**) from being achieved as they do not promote and encourage ethnomathematical perspectives in mathematics education curricula. While examining the mathematics education modules for the integration of ethnomathematical perspectives in mathematics education at University A and University C, it may be concluded that there are no guidelines for the incorporation of ethnomathematical perspectives. In this regard, the rules (**R**) constrained the possibilities of the integration of ethnomathematics in the activity system.

Furthermore, teacher educators and student teachers, which form part of the community in this activity system show evidence of tension between the community and objects. In this regard, teacher educators highlighted that cultural diversity may hinder the integration of ethnomathematics. This may be because it is difficult to accommodate and represent all diverse cultures in contextualising mathematics in learners' cultural contexts.

Activity System 3 is a mirror-reflection of Activity System 1 and represents student teachers' (**S**) experiences of learning contextualisation of mathematics without ethnomathematics. Although data revealed that student teachers are aware of the benefits of ethnomathematics, they lack PCK and skills to integrate it into their prospective classrooms. For example, Student Teacher C3 stated that "*I do not know how to teach using ethnomathematics*" (ST C3, PQ, Add I:133). Among the plausible explanations for these findings is that they do not use cultural artefacts in learning contextualisation of mathematics, as evident in activity system 1. Furthermore, another student teacher participant stated that ethnomathematics

> *came up as we were discussing in class. For example, if a student raises a point, and as a teacher answer that with something relational to whatever that is going on. That is when they bring the culture inside. It is not there in the guide.* (ST A3, FG, Add H:83)

In addition, other student teachers at University C also emphasised that ethnomathematics is not integrated into pre-service mathematics education modules (e.g., ST C2, PQ, Add I:128; ST C3, PQ, Add I:132; ST C4, PQ, Add I:136). The course materials (T) they use in the learning environment do not include ethnomathematics; this brings about a tension between the tools and outcome in the activity system. In this activity system, there is a lack of cultural resources that promote contextualisation of mathematics in learners' sociocultural contexts. Apprenticeship of observation is evident in this activity system as student teachers learn to teach mathematics in context through transmission approaches, as observed from their teacher educators.

There is also a tension between the community and the object of the activity system. For example, mentor teachers as part of the community (**C**) for student teachers' activity system do not integrate ethnomathematics as a teaching approach during WIL. Consequently, student teachers may be discouraged from using ethnomathematics in their own classrooms under the supervision of such mentor teachers. Among the possible explanations for these tensions is that the CAPS mathematics assessment seldom uses ethnomathematics contexts and, as a result, mentor teachers do not see the need to use the ethnomathematics approach.

From a CHAT perspective, there is a conflict between the teacher educators and student teachers' activity systems which are propelled by a lack of ethnomathematics integration, which student teachers consider essential in developing learners' ability to make the connection between learners' sociocultural contexts and school mathematics. The conflict between activity system 1 and activity system 3 reveals evidence of contraction of control (McNeil, 1999). In this case, the intended 'object' of preparing student teachers to contextualise mathematics by infusing ethnomathematics is not necessarily realised, as a result of the tensions highlighted above.

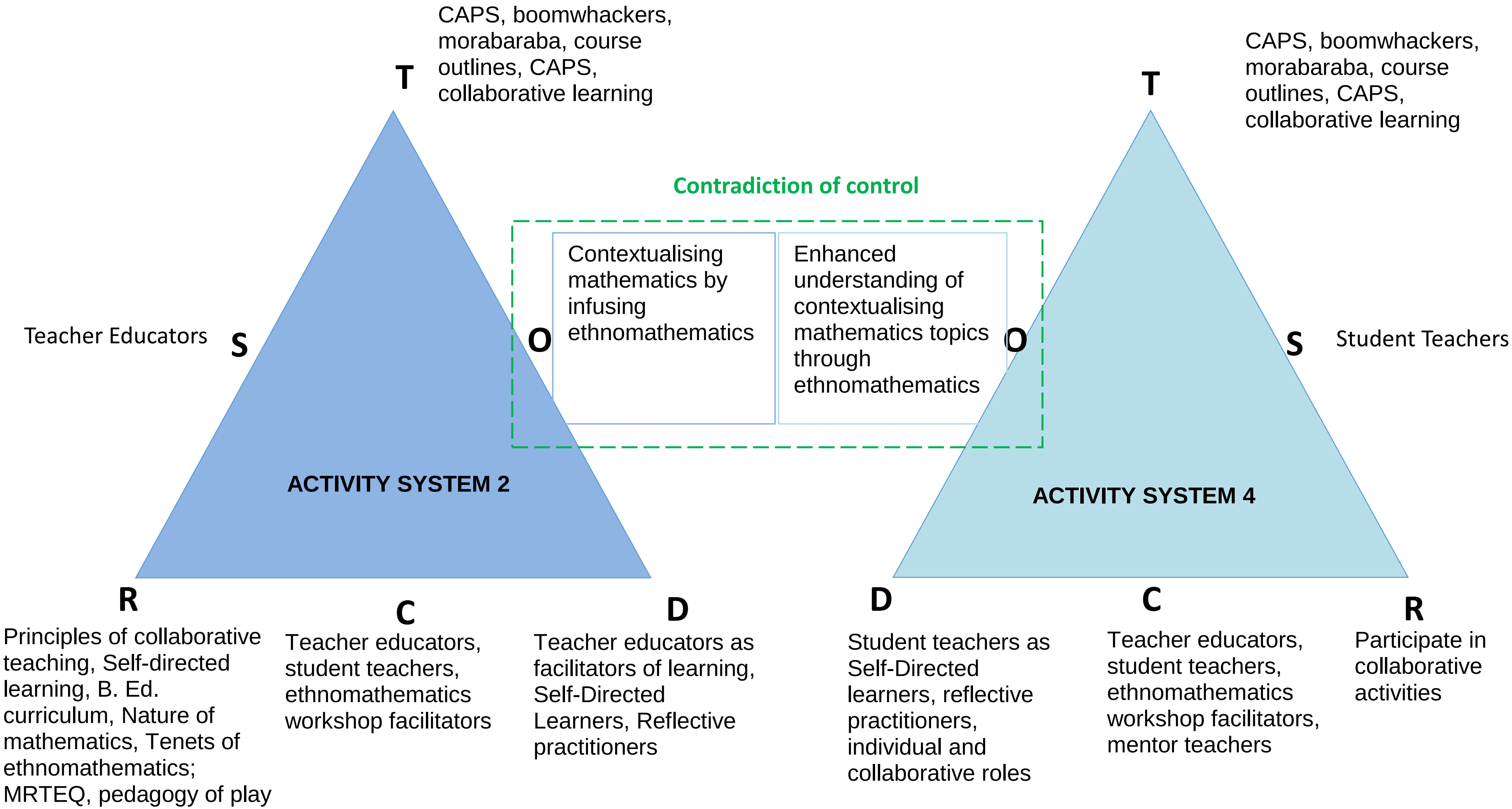


Figure 5-3: Third-generation CHAT employed at instructional level.

(Adopted from De Beer & Mentz, 2017; Havenga, 2019)

In the figure above, **Activity System 2**, like activity system 1, focuses on facilitation of contextualisation of mathematics but through the integration of ethnomathematics. In this activity system, the teacher educators and ethnomathematics workshop facilitators use pedagogy of play artefacts such as Morabaraba indigenous games and boomwhackers as tools (**T**) to develop student teachers' PCK knowledge and skills to infuse ethnomathematics in CAPS mathematics topics, which is an objective **(O)** of the activity system. Among the plausible explanations for these results is that teacher educators and facilitators select appropriate tools and strategies such as collaborative learning and inquiry-based learning to prepare student teachers to infuse ethnomathematics into their prospective classrooms. In this regard, the aim was to develop student teachers' adequate understanding of ethnomathematics perspectives and how they could be applied to contextualise mathematics in learners' sociocultural or everyday contexts.

In order to achieve the division of labour (**D**), teacher educators and ethnomathematics workshop facilitators encourage student teachers to actively participate in learning activities such as playing morabaraba indigenous games and music through boomwhackers. They also raise student teachers' awareness of how various cultures contributed to the development of various mathematical concepts. This was evident in comments such as "*It is very important for our students to remember that it was not just one culture that contributed to the western number system, but a lot of cultures from different parts of the world"* (TE B2, ES, Add G:56) and

> *When students develop lessons which they are to teach one day, they have to contextualise the mathematics to the specific school setting which they wish to teach – hence, they have to pay attention to indigenous games which learners play at break times and use a pedagogy of play approach to use this knowledge, mathematise the school mathematics content, and develop a lesson with this integrated knowledge to make the mathematics understandable, meaningful and accessible to their learners.* (TE B1, ES, Add G:47)

In so doing, student teachers are encouraged to find relevant ethnomathematics artefacts they can use in their prospective classrooms. The results provide evidence that teacher educators intended to promote student-teachers' SDL skills to find cultural practices that can be used to enhance their teaching approaches.

Activity System 4, which focuses on student teachers' learning of contextualisation of mathematics through ethnomathematics, is a mirror-reflection of activity System 2. The object (**O**) of this activity system is for student teachers to develop pedagogical knowledge and skills to infuse ethnomathematics in their prospective classrooms. In this case, student teachers are exposed to cultural artefacts such as morabaraba indigenous games (**T**). For example, one student teacher indicated that

> *They prepare us to use learners' cultural contexts. One of the things they taught us was on the morabaraba game. Geometry shapes were explored from the game, and we did some activities based on the game. This in a way was trying to expose us to some of the cultures and how we can use it in our classrooms*. (ST B3, ES, Add H:121)

Similarly, student teachers at University C indicated that the ethnomathematics workshop improved their pedagogical knowledge and skills on how they can integrate indigenous games and boomwhackers into the teaching and learning of mathematics. Among plausible reasons for these results is that facilitators, as expert-others, scaffolded student teachers' professional development in accordance with Warford's (2011) ZPTD. In addition, the role of the facilitators was found to be effective as student teachers, particularly at University C, did not have the knowledge to contextualise mathematics in ethnomathematics prior the intervention. Moreover, the results of student teachers at University C provide evidence of Warford's (2011) internalisation stage characterised by "critical reflection" (De Beer, 2017, p. 17). The results further suggest there is no tension between the tools (**T**) and object (**O**) of the activity system. The tools used supported and promoted the object of the activity system.

Furthermore, student teachers and their teacher educators still formed part of the activity system, but the division of labour included the student teachers as self-directed learners. As self-directed learners, they learn about relevant cultural artefact tools that could be applied in their own classrooms. As a result, self-directed learning was evident in the following comment:

> *During the presentations I could think of other ways I could incorporate traditional games in our classes. There are many other traditional games out there, so now during the intervention I saw the Professors presenting I could also think about the games that I know and people from home know, so they relate to those games, and I can use them to teach lessons*. (ST C1, FG, Add H:96)

Student teachers felt it is important to identify cultural practices or activities such as indigenous games (**T**) that learners are familiar with in order to contextualise mathematics.

However, the student teachers pointed out that it may be difficult to integrate ethnomathematics into the teaching and learning of mathematics as they consider it to be a time-consuming teaching approach. The integration of ethnomathematics approaches such as indigenous games or boomwhackers might not accommodate often prescribed time frameworks to cover the CAPS mathematics content. For example, one student teacher argued that "*It is very time-consuming,* *and the teacher will need more time to plan the lesson on how to use the game*" (ST C2, FG, Add H:101). This points to a tension between the rules (**R**) and the object (**O**) in the activity system. The results provide evidence that an ethnomathematics-based lesson requires lot of planning and implementation time.

Furthermore, tensions were also evident between the tools (**T**) and the object (**O**). For example, some student teachers believed that integrating indigenous games to teach mathematics might result in learners focusing on the context rather than the mathematics they need to learn. In this regard, a student teacher participant stated that *"Learners may take more time focusing on the cultural contexts than learning mathematics"* (ST B3, ES, Add H:121). Among the possible explanations for these tensions is that the use of indigenous games could result in learners focusing on the fun part of playing the game rather than learning through it. However, this tension did not necessarily result in a contraction of control (McNeil, 1999). In this case, the intended 'object' of preparing student teachers to contextualise mathematics by infusing ethnomathematics is realised.

5.10 CHAPTER SUMMARY

This chapter has reported results from teacher educators', the ethnomathematics expert's, and student teachers' semi-structured interviews, pre-intervention questionnaire and focus group interviews. The findings indicate that there is a general understanding of ethnomathematics amongst teacher educators, ethnomathematics expert and student teachers. However, in some instances it has been shown that there is a vague understanding of the concepts. While the participants acknowledge the importance of ethnomathematics in the teaching and learning of mathematics, there is a lack of preparation of student teachers on it, especially in pre-service mathematics education modules at University A and University C. On the other hand, there is evidence of its integration in mathematics education modules at University B. Furthermore, the ethnomathematics workshop at University C appears to have prepared student teachers in ethnomathematical perspectives. In the next chapter, I focus on, amongst other things, answering the research questions, which underpinned this study.

CHAPTER 1

- BACKGROUND AND CONTEXT OF THE STUDY

CHAPTER 2

- LITERATURE REVIEW

CHAPTER 3

- THEORETICAL AND CONCEPTUAL FRAMEWORKS

CHAPTER 4

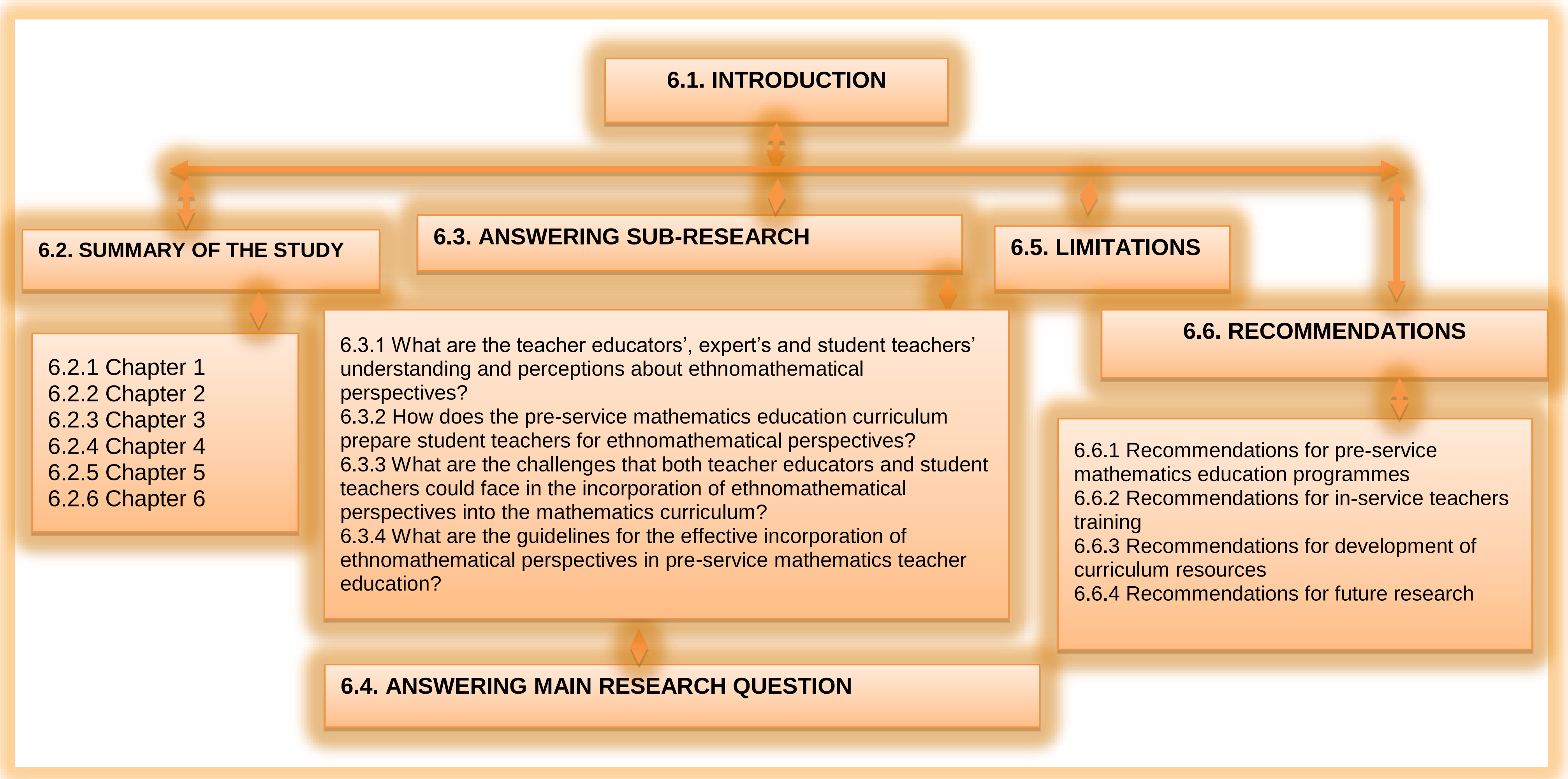
- RESEARCH DESIGN AND RESEARCH METHODOLOGY

CHAPTER 5

- PRESENTATION OF RESULTS AND THEIR INTERPRETATIONS

CHAPTER 6

- SUMMARY OF THE MAIN FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION


6.1. INTRODUCTION
6.2. SUMMARY OF THE STUDY
6.2.1 Chapter 1
6.2.2 Chapter 2
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6.6.1 Recommendations for pre-service mathematics education programmes
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6.6.3 Recommendations for development of curriculum resources
6.6.4 Recommendations for future research

CHAPTER 6

SUMMARY OF THE MAIN FINDINGS, LIMITATIONS, RECOMMENDATIONS, AND CONCLUSION

6.1 INTRODUCTION

The study set out to investigate the affordances of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa. The general theoretical literature on ethnomathematics, and specifically in the context of pre-service mathematics teacher education in South African universities, is inadequate when dealing with the numerous essential questions within the diversification discourse. Therefore, this chapter presents and discusses the research findings that emerged from the analysis of the semi-structured interviews, pre-intervention questionnaire, focus group interviews and document analysis data. The discussion in this chapter is organised according to the research questions which guided the study. Limitations and recommendations are also presented in this chapter.

The chapter begins by providing a summary of the chapters in the study.

6.2 SUMMARY OF THE STUDY

The chapter summary includes an overview of the chapters in this study.

6.2.1 Chapter 1

Chapter 1 provided the introduction and background to the study. The research problem was discussed, together with how the problem was identified. The research questions that assisted in addressing the research problem were outlined. The chapter also provided an overview of the methodological aspects of the current study.

6.2.2 Chapter 2

The second chapter was a survey of literature related to the current study. The nature of mathematics and state of mathematics in South Africa, particularly with regard to learners' underachievement, was also highlighted. The chapter focused on the intensive work that has already been done with regard to ethnomathematics in mathematics education. It is within this intensive body of knowledge in ethnomathematics that the gap was identified and addressed by the current study.

6.2.3 Chapter 3

The third chapter outlined the theoretical and conceptual frameworks. On the one hand, the rationale for sociocultural theory, in particular, Warford's (2011) ZPTD, was justified as a theoretical framework underpinning this research study. Furthermore, CHAT was also discussed as a versatile research lens. On the other hand, various intermediate theories and how they give relevance to a focus on ethnomathematics were also elaborated.

6.2.4 Chapter 4

The fourth chapter outlined the methodology of the study. In this chapter, the research methods and steps taken in describing the affordances of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa were elucidated. The rationale for a multiple case study as a research design was described. The choice of research instruments was also justified in Chapter 4. Moreover, quality criteria aspects which provide rigour for the current study were accounted for in this chapter. In addition, the ethnomathematics intervention workshop conducted in one of the selected universities was also discussed in this chapter.

6.2.5 Chapter 5

The fifth chapter presented an analysis and interpretation of the data which sought to provide insight into the affordances of ethnomathematics perspectives in pre-service mathematics teacher education at selected universities in South Africa. It offered an interpretive and analytical account of the data that were generated and collected during the study. The participants' demographic data were also presented in this chapter. Furthermore, the themes pertinent to the ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa were identified and interpreted. Lastly, a description was provided to explain how Engeström's third generation was applied to juxtapose two interrelated activity systems, as recommended by Mentz and De Beer (2017), and pertained to the current study.

6.2.6 Chapter 6

This chapter builds upon the previous chapter by focusing on providing answers to the research questions which guided this study.

6.3 ANSWERING SUB-RESEARCH QUESTIONS

In this section, a detailed focus in on the discussion of the main findings per research questions which guided the study:

Sub-research question 1: **What are the teacher educators', the expert's, and student teachers' perceptions about, and understanding of, ethnomathematical perspectives?** The teacher educators', ethnomathematics expert's, and student teachers' perceptions and understanding of ethnomathematics were investigated through the semi-structured and focus group interviews.

Sub-research question 2: **How does the pre-service mathematics education curriculum prepare student teachers for ethnomathematical perspectives?** This question focused on the preparation of student teachers' perceptions for the incorporation of ethnomathematical perspectives. It was investigated through semi-structured interviews, focus group interviews, pre-intervention questionnaire, and document analysis.

Sub-research question 3: **What are the challenges that both teacher educators and student teachers face in the incorporation of ethnomathematical perspectives in the mathematics curriculum**? Challenges towards incorporation of ethnomathematical perspectives in pre-service teacher education programmes were investigated through a semi-structured, pre-intervention questionnaire, and focus group interviews.

Sub-research question 4: **What are the guidelines for effective integration of ethnomathematics in pre-service mathematics teacher education programmes?** CHAT was used on an institutional plane, as mentioned in Chapter 4, to formulate the guidelines for developing student teachers' professional development in ethnomathematics.

6.3.1 What are the teacher educators', expert's and student teachers' understanding and perceptions about ethnomathematical perspectives?

The main aim of this sub-research question was to explore the participants' understanding and perceptions about ethnomathematics. The findings showed that the participants understand the ethnomathematics concept and hold positive perceptions about its place in mathematics classrooms.

Teacher educators and the expert perceive ethnomathematics as an indigenous way of doing and communicating mathematical ideas

Rosa (2020) perceived ethnomathematics as diverse ways of knowing, doing and learning mathematics within sociocultural contexts. Similarly, the findings of the study revealed that ethnomathematics is perceived as an indigenous way of doing and communicating mathematical ideas (see Chapter 5, section 5.5, sub-section 5.5.1.). Teacher educators' and the ethnomathematics expert's findings suggest that throughout human history, mathematics has always been part of people's daily activities. The contention is that mathematics can be traced back in human history and, as such, it should not only be viewed as a human activity, but taught from that standpoint. Ethnomathematics acknowledges that indigenous houses, indigenous games, amongst others, found in various cultural practices tell a story of mathematics.

Teacher educators and student teachers perceive ethnomathematics as the relationship between dynamic, evolving cultures and mathematics

The findings of this study showed that ethnomathematics is perceived as the relationship between dynamic, evolving cultures and mathematics. Ethnomathematics perceived as a dynamic and evolving concept embraces both historical and modern cultural practices across various cultural groups. Among the conceivable explanations for these findings is that the past and present cultural practices are understood to have underlying mathematical principles or concepts. The present findings also suggest that a focus on ethnomathematics as a stagnant concept limited to historical practices could limit the possibilities of ethnomathematics as an innovative instructional approach (see Chapter 5, section 5.5, sub-section 5.5.2).

Ethnomathematics may enhance learners' understanding of abstract mathematics concepts

Research has shown that the integration of ethnomathematics may deepen conceptual understanding of mathematics concepts (Moloi, 2015; Moloi et al., 2021; Rosa & Shirley, 2016; Sharma & Orey, 2017). Similarly, in this study it was revealed that ethnomathematics may enhance learners' understanding of abstract mathematics concepts. The participants acknowledged that mathematics is generally considered to be a difficult subject as it is predominantly taught in an abstract manner without taking into consideration the learners' cultural backgrounds. As a result, the participants strongly believed that ethnomathematics could help learners learn mathematics with understanding. The findings suggest that ethnomathematics acknowledges that learners come to mathematics classrooms with a wealth of knowledge and experiences shaped by their cultural backgrounds. Thus, mathematics teachers should utilise such experiences for the benefit of learners (see Chapter 5, section 5.6, sub-section 5.6.1.). Learners' knowledge filtered through their cultural backgrounds should be taken into consideration in their learning endeavours. When learners are taught mathematics from the level of their knowing based on their culturally-based prior knowledge, it might accelerate their abilities to make connections between mathematical ideas. When teachers teach mathematics from what learners know from their cultural contexts, mathematics may become accessible for learners. The current findings also suggest that mathematical examples from learners' cultural practices or backgrounds could be used as concrete knowledge to help them understand the abstract mathematical concepts. The findings also concur with De Beer and Van Wyk (2019) that learners do not enter the STEM classroom as tabula rasa, and they almost always have localised IKS that could contextualise the often-abstract curriculum content better. The current findings add substantially to our understanding of ethnomathematics as a concrete bridge to the abstract world of mathematics.

Ethnomathematics may develop learners' awareness of the relevance of mathematics in real-life contexts

Research has shown that ethnomathematics provides learners with opportunities to experience mathematics in their everyday life (Madusise, 2015; Moloi et al., 2021; Rosa & Shirley, 2016; Sharma & Orey, 2017). Similarly, in this study it was found that ethnomathematics may develop learners' awareness of the relevance of mathematics in real-life contexts (see Chapter 5, section 5.6, sub-section 5.6.2). According to the participants, most of the learners are not aware that mathematics is linked to their everyday life. Among the plausible explanations for these findings is that there are those learners who do not know that mathematics exists in their everyday contexts. Consequently, the findings provide evidence that when learners are taught through ethnomathematics, they may develop awareness that mathematics is part of their everyday life. Ethnomathematics also provides teachers with opportunities to develop methods which will help learners to identify and reflect on the mathematics found around them. There is a possibility that ethnomathematics may help learners to develop reflective and analysis skills based on the awareness of mathematics linked to their real-life experiences.

Ethnomathematics may develop awareness that every culture contributed to mathematics development

Research has shown that the aim of integration of ethnomathematics in classrooms is to illustrate that learners' underrepresented cultures do contribute to mathematical knowledge and thinking (Chahine, 2020; D'Ambrosio & Rosa, 2017; Shirley & Palhares, 2016). Likewise, the findings of the study showed that ethnomathematics may promote cultural inclusivity of previously excluded cultures into the teaching and learning of mathematics. There are cultures that are excluded in the mainstream mathematics curriculum offered in schools, learners often cannot see themselves in the mathematics curriculum offered in schools, as explained by the expert participant. This could be because Western mathematics curricula do not take into consideration the contributions of other cultures towards mathematics development (see Chapter 5, section 5.6, sub-section 5.6.3). The mathematics taught in schools should be seen as the product of many diverse cultures. Among the possible explanations for these findings is that when learners' cultures are represented in the mathematics curriculum, they become motivated and know that their cultures are valued in the teaching and learning of mathematics. By so doing, learners could develop a sense of mathematical ownership. The findings concur with Van der Walt et al. (2019) that when learners learn to see mathematics only from a western perspective, they may believe that their culture is less powerful and might not work with mathematics or, even worse, that they cannot work with the mathematics that they see in schools, as it is not their own.

6.3.2 How does the pre-service mathematics education curriculum prepare student teachers for ethnomathematical perspectives?

The main aim of this sub-research question was to explore the preparation of student teachers on ethnomathematics in pre-service mathematics education. Thus, through this question I intended to find out whether student teachers are trained or not trained in ethnomathematics as one of the innovative instructional approaches. The findings presented below provide answers to the sub-research question:

Lack of focus on ethnomathematics in mathematics modules

Research has shown teachers' low level of ethnomathematics awareness is often linked to pre-service teacher education, which does not prepare them adequately (Abiam et. al., 2016; Aikpitanyi & Eraikhuemen, 2015; Orey & Rosa, 2007). Similarly, the findings of this study revealed a lack of preparation of student teachers on ethnomathematics in pre-service mathematics education at University A and University C (see Chapter 5, section 5.7, sub-section 5.7.1). The findings provide evidence that ethnomathematics is not taught in mathematics education modules. As a result, student teachers felt strongly that a lack of focus on ethnomathematics in mathematics education leaves them underprepared to integrate ethnomathematics in their prospective classrooms. Subsequently, it became evident that student teachers lack knowledge to integrate ethnomathematics in their prospective classrooms. The findings also concur with Spangenberg (2020) who argued that many student teachers find it challenging to integrate ethnomathematics in their classrooms. The findings of this study also indicate that student teachers who are not taught ethnomathematics may not know how they can use it as an instructional pedagogy in the mathematics classrooms.

Integration of history of mathematics, indigenous games, music, and boomwhackers to develop student teachers' ethnomathematics' pedagogical knowledge and skills

Research has recommended that teacher education programmes offer courses to popularise and sensitise mathematics (student) teachers on the use of ethnomathematics (Balamurugan, 2015; Seroto, 2012). Hence, Katsap and Silverman (2008) stressed that there is no justification to avoid the integration of ethnomathematical perspectives in pre-service teacher education programmes, particularly in mathematics education curricula. In this study, it was found that student teachers are equipped with ethnomathematical perspectives in University B. The findings further revealed integration of the history of mathematics, indigenous games, and music (boomwhackers) as some of the approaches to integrate ethnomathematics in pre-service mathematics teacher education (see Chapter 5, section 5.7, sub-section 5.7.2). Firstly, it was revealed that student teachers are exposed to the history of mathematics which, amongst others, focuses on mathematics techniques and methods found in various cultural groups. Such techniques are understood to develop learners' confidence and abilities to learn mathematics concepts and skills such as multiplication without being dependent on calculators, according to the participants. The findings also suggested that the integration of diverse methods and techniques found in various cultures might provide multiple ways of teaching and learning mathematics concepts such as multiplication.

Secondly, the findings revealed that some teacher educators integrate indigenous games to equip student teachers with knowledge and skills to integrate ethnomathematics in the mathematics classroom (see Chapter 5, section 5.7, sub-section 5.7.2.1). The argument is that indigenous games play an essential role in contextualising mathematics concepts. The findings are consistent with Moloi et al. (2021) and Van der Walt et al. (2019) who found that mathematical concepts such as quadrilaterals could be taught using indigenous games. Moloi (2014) also discovered that indigenous games help to perform high cognitive and synthesis skills. The findings of this study further suggested that the use of indigenous games might be meaningful when linked with mathematics activities, according to student teacher participants. The findings insinuate that problem-based or inquiry-based learning is essential in an ethnomathematics-based learning environment. The view is that engaging in mathematics activities based on indigenous games might provide student teachers with opportunities to mathematise. Among the plausible explanations for this finding is that when mathematics is contextualised through indigenous games, the role of mathematics activities might be to bring the abstract mathematical symbols to such contexts. Consequently, the transition from cultural contexts such as indigenous games to mathematics concepts might be established (see Chapter 5, section 5.7, sub-section 5.7.2.1).

Lastly, the findings of the study revealed that student teachers perceive the integration of music and boomwhackers as a new perspective to the teaching and learning of fractions (see Chapter 5, section 5.7, sub-section 5.7.2.3). Through integrating music and boomwhackers, the concept of fractions may be simplified and understood by learners. The findings of this study concur with the earlier findings of Van der Walt et al. (2019), which found that music and boomwhackers might be used to teach mathematics concepts such as fractions.

Teacher educators and the expert acknowledge they need to prepare student teachers on ethnomathematics towards changing their mindset about the nature of mathematics

Research has demonstrated that an important characteristic of ethnomathematics is the transformational power it has to help rethink the nature of mathematics (Bhuda & Pudi, 2020; Iseke-Barnes, 2000; Rosa & Orey, 2016). Similarly, the findings of this study revealed that teacher educators and the ethnomathematics expert strongly believed that the need to prepare student teachers in ethnomathematics is in order to change or transform their mindset about the nature of mathematics (see Chapter 5, section 5.7, sub-section 5.7.3). The findings might be influenced by the fact that student teachers enter pre-service mathematics teacher education programmes with preconceived ideas about mathematics as an abstract and culture-free subject. The participants felt there is a need to challenge the dominant platonist or traditional perspective that does not acknowledge and embrace contributions of other cultures in mathematics classrooms. In other words, the findings suggest that ethnomathematics advances transformation in the teaching and learning of mathematics. This observation is also strengthened by student teachers' findings, which acknowledge the shift towards humanistic philosophical orientation that acknowledge the use of learners' cultural backgrounds in the teaching and learning of mathematics. As a result, there is a possibility that the integration of ethnomathematics could help reshape student teachers' views concerning the nature of mathematics. The findings of this study provide evidence that preparation of student teachers in ethnomathematics may help them to perceive mathematics as a cultural product, according to teacher educators, student teachers and the expert participant. The findings further uphold the argument that ethnomathematics aims to demystify school mathematics as a final, permanent, absolute, unique form of knowledge focusing on changing the misperception that culture has no place in mathematics (Chahine, 2011, 2020; D'Ambrosio & Rosa, 2017). Hence, Petersen et al. (2020) argued that failure to transform perceptions about pedagogical orientations might result in student teachers imitating the way they were taught in their school years.

6.3.3 What are the challenges that both teacher educators and student teachers could face in the incorporation of ethnomathematical perspectives into the mathematics curriculum?

Sub-research question 4 focuses on the challenges that could hinder the effective integration of ethnomathematics. The study revealed the following challenges could impede the incorporation of ethnomathematical perspectives: cultural diversity, curriculum responsiveness, lack of contextualised textbooks, lack of ethnomathematics integration, and discouragement of student teachers by mentor teachers towards integrating ethnomathematics during WIL, technology approaches and time constraints. These challenges are discussed below:

Cultural diversity might hinder integration of ethnomathematics in the classroom

Research has demonstrated that cultural diversity is considered as a challenge to ethnomathematics integration (Sunzuma, 2019; Sunzuma & Maharaj, 2019). Similarly, the findings of the study revealed that cultural diversity could pose a challenge to ethnomathematics in the teaching and learning of mathematics, particularly because of multicultural classrooms. In South Africa, both teachers and learners come from diverse cultural backgrounds with diverse cultural practices and methods. Learners may not be familiar with cultural contexts that teachers are using and as a result they might be confused and lose interest in learning. The findings highlight the possibility of disadvantaging other learners, especially those that cannot relate to cultural practices or examples used by the teachers. Among possible reasons for the challenges is that it will become difficult for mathematics teachers to accommodate all learners when integrating ethnomathematics. The findings are consistent with Gerdes (2001) who argued that mathematical thinking and methods are quite different in different cultures. In other words, teachers may find it challenging to come up with relevant cultural contexts to accommodate all the learners. The findings suggest learners' sociocultural backgrounds be considered in an ethnomathematics-based learning environment. Hence, teachers should ensure there is a balance of cultures and find cultural activities that can be integrated into the classroom (Brandt & Chernoff, 2015; Gerdes, 2001). Although cultural diversity may be perceived as a challenge, the findings of this study also contrarily revealed that it may present learners with opportunities to explain mathematical concepts in the contexts of their unique cultures. The findings provide evidence that suggests that cultural diversity may offer learners opportunities to share their understanding of mathematics concepts from their cultural perspectives (see Chapter 5, section 5.8, sub-section 5.8.1).

The CAPS curriculum is not responsive towards ethnomathematics

The findings of the study showed that the CAPS curriculum is not responsive to ethnomathematics (see Chapter 5, section 5.8, sub-section 5.8.2). Some teacher educators believed that the curriculum does not sufficiently cover ethnomathematics. Although the curriculum acknowledges IKS, it is not explicit on how indigenous knowledge could be used to contextualise mathematics content, as articulated by one of the teacher educators. The findings further suggested the teacher educators felt strongly that the effective integration of ethnomathematics is influenced by how it is accommodated in the CAPS mathematics curriculum.

On the other hand, findings from the expert participant revealed that the curriculum is responsive towards ethnomathematics as it advocates for the integration of learners' social, cultural, and environmental backgrounds in the teaching and learning of mathematics, as reflected in the specific aims of mathematics (see Chapter 5, section 5.8, sub-section 5.8.1). The expert participant argued that the onus is on teachers' pedagogical knowledge and skills to achieve specific aims of mathematics through the integration of learners' social, cultural, and environmental backgrounds, which are understood as ethnomathematics contexts.

Lack of learners' cultural contexts in mathematics textbooks

Researchers have found that textbooks and other curricular materials have given little attention to learners' cultural or indigenous contexts (Gavarrete, 2012; Madusise, 2020; Sunzuma, 2019), which may pose a challenge to ethnomathematics. Similarly, the findings of the study revealed that a lack of contextualised textbooks might hinder the effective integration of ethnomathematics. Textbooks are understood to be the main teaching and learning resources in the mathematics classroom, and a lack of focus on ethnomathematics in textbooks could negatively impact its integration. The participants strongly believed that the mathematics textbooks that are available do not include ethnomathematics aspects. Thus, the findings suggest that textbooks are mainly written in abstract methods without taking into consideration learners' immediate cultural backgrounds. The contexts that are often used in the textbook are foreign or do not relate to learners' immediate cultural contexts. Thus, the mathematical examples or activities found in many textbooks have no relevance to learners' cultural practices (see Chapter 5, section 5.8, sub-section 5.8.3).

Lack of ethnomathematics integration and discouragement of student teachers by mentor teachers towards integrating ethnomathematics during work-integrated learning

Researchers such as Seroto (2012) and Rosa and Gavarrete (2017) found that mathematics teachers are reluctant to integrate ethnomathematics into their classrooms. Similarly, the findings of this study showed that mentor teachers do not integrate ethnomathematics in their classrooms, and also discourage student teachers from integrating it during WIL (see Chapter 5, section 5.8, sub-section 5.8.4). The findings provide evidence that student teachers do not receive a lot of support from their mentor teachers during WIL and this damages student teachers' confidence in integrating ethnomathematics. Among the apparent explanations for these findings is that student teachers have the perception that mentor teachers are reluctant to change as they still rely on textbooks as the main source of teaching. The findings also suggest that what student teachers learn theoretically in their mathematics education modules may often not be realised in practice.

Technology approaches might hinder integration of ethnomathematics in the teaching and learning of mathematics

Research has demonstrated that technology pedagogies are considered a challenge to the integration of ethnomathematics in the mathematics classroom (Sunzuma & Maharaj, 2019). The argument is based on the perception that reluctance to integrate ethnomathematics might be attached to the preconceived belief related to the nature of IKS as being backward and push away from technological progress (Chahine et al., 2013). Similarly, the findings of the study revealed that teacher educators and student teachers are of the perception that technology pedagogies might hinder the integration of ethnomathematics in the classroom. The 21st century classrooms are characterised by learners who are technologically driven and, as such, using ethnomathematics may possibly be irrelevant to them, according to the teacher educators and student teachers. Among the possible explanations for these findings is that modern mathematics classrooms are predominantly equipped with technology resources rather than ethnomathematics resources. The findings infer that more focus and preference is dedicated to technology than ethnomathematics approaches. While researchers such as Hidayat et al. (2020) contended that technological development makes culture more forgotten, the findings of this study revealed that both ethnomathematics and technology might be amalgamated in the teaching and learning of mathematics. In such instances, technology may be considered as a tool to advance ethnomathematics (see Chapter 5, section 5.8, sub-section 5.8.5).

Integration of ethnomathematics in the teaching and learning of mathematics is perceived as time-consuming

Research has shown that teachers tend to use transmission strategies to drill learners on rote examination procedures as integration of ethnomathematical perspectives will consume too much of the limited teaching time (Mbusi, 2011; Naresh, 2015; Seroto, 2012; Sunzuma, 2019). Similarly, the findings of the study revealed that the integration of ethnomathematics in the teaching and learning of mathematics could be time-consuming (see Chapter 5, section 5.8, sub-section 5.8.6). Ethnomathematics requires not only a lot of teaching time but planning as well. With limited timeframes often prescribed through pacesetters and work-schedules, it may not be realistic to teach through ethnomathematics. The findings also suggested that teaching and learning time could be lost as a result of learners focusing on the ethnomathematics contexts instead of mathematics found in such contexts. The contention is that teachers should pay attention and observe the cultural practices activities learners engage on in order to integrate contexts they are familiar with.

6.3.4 What are the guidelines for the effective incorporation of ethnomathematical perspectives in pre-service mathematics teacher education?

Sub-research question 4 focused on the guidelines that could guide the preparation of student teachers on ethnomathematics pedagogies as part of their professional development in pre-service mathematics teacher education programmes. To take the analysis further, I used CHAT on an institutional plane, as mentioned in Chapter 4, to formulate the guidelines for developing student-teachers' professional development in ethnomathematics (Figure 6-1).

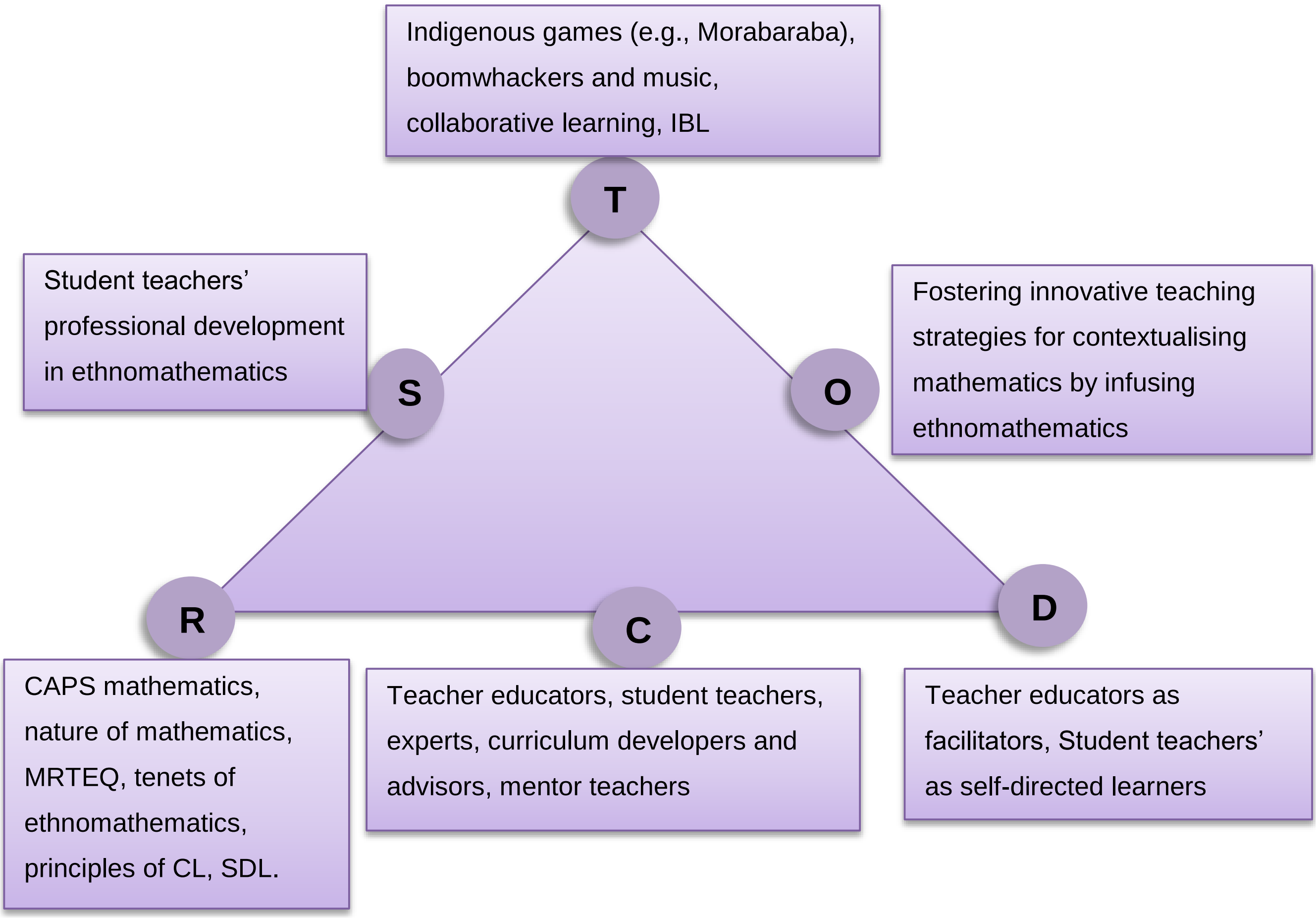

Figure 6-1: Guidelines for student teachers' professional development on ethnomathematics perspectives in pre-service mathematics teacher education based on CHAT.

The student teachers' professional development workshop serves as a subject of the activity system where the object is fostering innovative teaching strategies for contextualising mathematics by infusing ethnomathematics. Ethnomathematics is one of the innovative teaching strategies which draws from learners' cultural backgrounds. Ethnomathematics not only creates an interesting and fun learning environment, but it also promotes the connection between mathematics and real-life contexts. When student teachers are exposed to ethnomathematics, they develop knowledge and skills, which they use in their prospective mathematics classroom. Thus, they may become self-directed learners driven by a desire to find cultural backgrounds that can be applied to their unique mathematics classroom contexts. They look out for relevant cultural practices of activities that they may integrate in the teaching and learning of mathematics. SDL skills should be one of the guidelines underpinning student teachers' and teachers professional development in science (in this case ethnomathematics) (De Beer & Mentz, 2016, 2019; Sebotsa, 2020).

There is a necessity to prepare student teachers in ethnomathematics approaches to enhance their understanding of contextualising CAPS mathematics which is one of the rules (R) underpinning the activity system. Thus, student teachers should have a knowledge of the mathematics curriculum and its specific aims concerning contextualisation of mathematics and how it can be achieved in their prospective classrooms. Furthermore, through integration of ethnomathematics, student teachers are likely to perceive mathematics from the humanistic philosophical orientation and teach it accordingly (D'Ambrosio, 2016). Thus, knowledge of the curriculum should be one of the guidelines underpinning student teachers' professional development in ethnomathematics.

Furthermore, there is a need to prepare student teachers in knowledge and skills to integrate ethnomathematics using various cultural artefacts (**T**) in their prospective mathematics classrooms. Van der Walt et al. (2019) shed light on the necessary cultural artefacts (**T**) that can be utilised to contextualise mathematics. These artefacts were adopted in my research, with student teachers participating in the Morabaraba game and music, amongst others, during the intervention at University C (see Chapter 4, section 4.7). It is equally important for student teachers to analyse cultural artefacts in order to elicit mathematical ideas or concepts embedded in such artefacts. The contention is that through analysis, student teachers could develop skills to guide their prospective learners in recognising the link between cultural artefacts and mathematics.

The community of the activity system involves teacher educators, student teachers, experts, the Department of Education, curriculum developers and advisors, as well as mentor teachers. By involving all the stakeholders, the amalgamation between field-based and academic-centred concepts (Warford, 2011) in terms of contextualising mathematics through ethnomathematics in classrooms could be realised. The data showed that student-teachers are often discouraged from using ethnomathematics during teaching practice. In other words, student teachers appear not to enjoy support for the integration of ethnomathematics from the mentor teachers. Mentor teachers could also be experiencing pressure from the subject advisors to cover the curriculum within the prescribed time. There is also a need for the DBE and curriculum advisors to be involved as data revealed the CAPS mathematics curriculum is non-responsive towards ethnomathematics. The mathematics curriculum is not explicit on how contextualisation of mathematics through learners' social, cultural, and environmental backgrounds could be realised in mathematics classrooms.

6.4 ANSWERING THE MAIN RESEARCH QUESTION

The study sought to answer the following main research question:

What are the affordances of ethnomathematical perspectives in pre-service mathematics teacher education?

Van der Walt et al. (2019) argued that there is "a need for research invested in Mathematics [student] teachers' PCK in their own local and IK contexts, and their own readiness to contextualise and mathematise it" (p. 220). This study was conducted to explore, amongst others, student teachers' understanding and perceptions about ethnomathematical perspectives linked to learners' IKS contexts. Although teacher educators and student teachers from three selected universities demonstrated on a continuum ranging from well-informed to vague, limited and incomplete understanding of the ethnomathematics concept and its possible benefits in the teaching and learning of mathematics (first affordance), the findings of this study revealed that two (University A & University C) out of three universities are not preparing student teachers in ethnomathematical perspectives. Student teachers in these two universities indicated that a lack of focus on ethnomathematics in pre-service mathematics teacher education curriculum leaves them underprepared to contextualise mathematics in their prospective classrooms. The findings also highlight that student teachers lack pedagogical knowledge and skills to contextualise mathematics topics by infusing ethnomathematics contexts. These limitations suggest that student teachers who are not prepared in ethnomathematics may find it challenging to contextualise mathematics in learners' cultural backgrounds as a focal point of implementing the CAPS mathematics curriculum.

Furthermore, this study not only investigated how pre-service mathematics teacher education prepares student teachers in ethnomathematics, but also sought to scaffold student teachers' professional development, particularly at University C, in an attempt to enhance their pedagogical knowledge and skills on ethnomathematics through Warford's (2011) ZPTD. The findings provide evidence that student teachers who participated in the ethnomathematics intervention workshop had the opportunity to engage in mathematics in many cultures— the Morabaraba game, music, and boomwhackers activities—to learn how ethnomathematics can be integrated in mathematics lessons. Through the ethnomathematics intervention workshop, student teachers were able to learn how mathematics concepts such as multiplication can be contextualised through using multiplication methods and techniques found in various cultures (e.g., Chinese, Egyptian cultures). Student teachers further acknowledged that the integration of multiplication techniques can develop student cognitive abilities in performing multiplication without calculators. Similarly, these student teachers at University C, like those at University B who were prepared in ethnomathematics, explained how engaging in the Morabaraba game exposed them to how the game can be used to develop learners' strategic abilities and conceptual understanding in the learning of 2D-geometry concepts. In addition, student teachers felt strongly that the integration of music through boomwhackers could bring a new learning perspective to the concept of fractions.

Moreover, teacher educators from the three selected universities, regardless of whether they integrate or do not integrate ethnomathematics in their pre-service mathematics education modules, acknowledged the need to prepare student teachers on ethnomathematical perspectives. Among the possible explanations for these findings is that student teachers have experienced mathematics as a culture-free abstract subject during their 12 years of schooling. As a result, student teachers might lack knowledge on the importance of cultural contributions towards understanding the nature of mathematics. The need to change the student teachers' mindset about the nature of mathematics was further strengthened by the expert participant who also illustrated the importance of equipping student teachers with philosophical orientations other than the Platonist perspective.

While the teacher educators and expert based the need to prepare student teachers on the philosophical orientations, student teachers perceived the need from pedagogical orientations. Thus, student teachers, particularly those at University C who attended the ethnomathematics workshop, illustrated that it is important for pre-service mathematics teacher education to prepare them in ethnomathematical perspectives, as it will empower them to integrate learners' cultural or everyday contexts into the teaching and learning of mathematics. The student teachers pointed out that when they are prepared – to a certain extent - for ethnomathematics, they may not limit their teaching strategies to the traditional chalk-and-talk approaches they were exposed to during their 12 years of schooling but may include innovative approaches such as ethnomathematics. Thus, the second affordance focused on preparation of student teachers for ethnomathematics perspectives in pre-service mathematics teacher education.

Furthermore, the third affordance themes revealed challenges that could hinder the effective integration of ethnomathematics into the teaching and learning of mathematics. The following challenges were found: the CAPS mathematics curriculum is not responsive towards ethnomathematics; the lack of contextualised textbooks; the mentor teachers' discouragement of student teachers towards integrating ethnomathematics during teaching practice; cultural diversity; technology approaches; and it is time consuming. These are seen as numerous factors that might influence the teaching and learning of mathematics using ethnomathematics.

Lastly, the fourth affordance focused on the importance of the ethnomathematics workshop as an activity system that can develop student teachers' professional development in ethnomathematics. In this regard, the findings indicated the use of the appropriate cultural artefacts or tools as one of the key guidelines. Thus, student teachers should be prepared for how they can use various tools from the learners' cultural or everyday contexts to contextualise mathematics. Furthermore, learning activities should be context-based such that the process of mathematisation is realised and experienced.

6.5 LIMITATIONS OF THE STUDY

I faced several limitations while carrying out this research and, as a result, they should be noted when interpreting the results. The limitations include the few participants; the impact of COVID-19 on data collection, and intervention, as described below:

Firstly, the sample involved few participants (n=24) and limited itself to only three out of 26 public universities in South Africa. Initially I had proposed to collect data from at least 10 student teachers at each selected university, which would have made a total of 30 student teacher participants. However, only a few (17) student teachers showed an interest in the study. Likewise, six out of twelve initially proposed teacher educators were available to participate in the study. In addition, out of two ethnomathematics experts who were invited, only one responded positively. As a result, the findings of this study cannot with certainty be generalised to larger populations as is the case with a qualitative case study research design.

Secondly, data were collected during the COVID-19 pandemic which affected data collection negatively. At University B participants were reluctant to participate in this study; as a result, only a few (three student teachers) showed willingness to participate in the study through electronic responses (one student teacher responded) and telephonic interviews (two student teachers participated). The electronic submissions provided little room for prompts on the participants' responses. As a result, electronic responses interviews produced less data than a face-to-face interview. Had time allowed, it would have been interesting to note how the perceptions and views of the participants submitted electronically would have been in face-to-face interviews, which allows sufficient time for in-depth prompts and follow-up.

Thirdly, the ethnomathematics intervention workshop was only conducted at University C, where only a few student teachers (n=10) were invited due to COVID-19 restrictions. Hence, I could not conduct interventions at all the selected universities. It would have been advantageous to conduct workshop with a large sample. Furthermore, the student teachers who participated in the intervention did not develop and implement the lessons in actual classrooms. In this regard, it would have been beneficial to observe student teachers' internalisation stage (Warford, 2011) in their classrooms during WIL. It would have been valuable to observe how student teachers integrated ethnomathematics in their classrooms during teaching practices. Moreover, the workshop was a once off engagement of student teachers with ethnomathematics. There had been no follow-up workshop or assignment that student teachers had to submit in future.

6.6 RECOMMENDATIONS

Regardless of its limitations, having considered the findings of the research study, I make the following recommendations:

6.6.1 Recommendations for pre-service mathematics education programmes

I recommend the integration of ethnomathematics into pre-service mathematics teacher education, particularly in mathematics education modules or intervention workshops, to develop student teachers' pedagogical content knowledge and skills to infuse ethnomathematics in their prospective classrooms. The guidelines offered above provide opportunities for pre-service teacher education institutions to restructure, where necessary, the existing mathematics education and mathematics methodology courses for the integration of ethnomathematics.

6.6.2 Recommendations for in-service teachers training

I recommend in-service teachers' professional development interventions or workshops to develop mathematics teachers' awareness of the importance of ethnomathematics in the teaching and learning of mathematics. In addition, such training should also be extended to curriculum advisors and developers to assist them in developing guidelines towards contextualising the mathematics curriculum through learners' social and cultural backgrounds in accordance with mathematics' specific aims. Equipping in-service mathematics teachers with knowledge and skills to integrate ethnomathematics may minimise the discouragement student teachers experience towards using ethnomathematics during WIL.

6.6.3 Recommendations for development of curriculum resources

The findings of this current study revealed that a lack of curriculum resources such as textbooks based on ethnomathematics contexts is a challenge to the integration of ethnomathematics. I recommend that mathematics education researchers in ethnomathematics, in collaboration with the DBE, need to compile a textbook(s) with all possible different cultural aspects included - as a resource for teachers.

6.6.4 Recommendations for future research

It became evident in this research study that the integration of ethnomathematics is influenced by various factors such as curriculum responsiveness. While this research did not only focus on the use or non-use of ethnomathematics in pre-service mathematics education modules, the ethnomathematics intervention workshop scaffolded student teachers' knowledge on ethnomathematics. However, I did not focus on student teachers' transfer of knowledge they gained in the workshop to their actual classroom practices, particularly during their WIL. Therefore, I recommend further research which could focus on intervention workshops and student teachers' actual classroom practices in contextualising mathematics through ethnomathematics.

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ADDENDUM A: ETHICAL CERTIFICATE

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X1290, Potchefstroom
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Senate Committee for Research Ethics
Tel: 018 299-4849
Email: nkosinathi.machine@nwu.ac.za

ETHICS APPROVAL LETTER OF STUDY

Based on approval by the **Education Sciences Research Ethics Committee (EduREC)** on 24 March 2022, the Education Sciences Research Ethics Committee hereby **approves** your study as indicated below. This implies that the North-West University Senate Committee for Research Ethics (NWU-SCRE) grants its permission that, provided the special conditions specified below are met and pending any other authorisation that may be necessary, the study may be initiated, using the ethics number below.

Study title: The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa

Study Leader/Supervisor (Principal Investigator)/Researcher: Prof M van der Walt **Student / Team:** KS Mabotja (PhD student - 25876619), Prof JJJ de Beer

Ethics number:

N	W	U	-	0	0	7	9	2	-	1	8	-	A	2

Status: S = Submission; R = Re-Submission; P = Provisional Authorisation; A = Authorisation

Application Type: Single study

Commencement date: 25/03/2021 **Risk:** Low

Expiry date: 25/03/2022

Approval of the study is initially provided for a year, after which continuation of the study is dependent on receipt and review of the annual (or as otherwise stipulated) monitoring report and the concomitant issuing of a letter of continuation.

Special in process conditions of the research for approval (if applicable):

General conditions:

While this ethics approval is subject to all declarations, undertakings and agreements incorporated and signed in the application form, the following general terms and conditions will apply:

- *The study leader/supervisor (principle investigator)/researcher must report in the prescribed format to the ES-REC:*
  - *annually (or as otherwise requested) on the monitoring of the study, whereby a letter of continuation will be provided, and upon completion of the study; and*
  - *without any delay in case of any adverse event or incident (or any matter that interrupts sound ethical principles) during the course of the study.*
- *The approval applies strictly to the proposal as stipulated in the application form. Should any amendments to the proposal be deemed necessary during the course of the study, the study leader/researcher must apply for approval of these amendments at the ES-REC, prior to implementation. Should there be any deviations from the study proposal without the necessary approval of such amendments, the ethics approval is immediately and automatically forfeited.*
- *Annually a number of studies may be randomly selected for an external audit.*
- *The date of approval indicates the first date that the study may be started.*
- *In the interest of ethical responsibility, the NWU-SCRC and ES-REC reserves the right to:*

1

- *request access to any information or data at any time during the course or after completion of the study;*
- *to ask further questions, seek additional information, require further modification or monitor the conduct of your research or the informed consent process; – withdraw or postpone approval if:*
  - *any unethical principles or practices of the study are revealed or suspected;*
  - *it becomes apparent that any relevant information was withheld from the ES-REC or that information has been false or misrepresented;*
  - *submission of the annual (or otherwise stipulated) monitoring report, the required amendments, or reporting of adverse events or incidents was not done in a timely manner and accurately; and / or · new institutional rules, national legislation or international conventions deem it necessary.*

The ES-REC would like to remain at your service as scientist and researcher, and wishes you well with your study. Please do not hesitate to contact the ES-REC or the NWU-SCRE for any further enquiries or requests for assistance.

Yours sincerely

Prof Jako Olivier
Chairperson NWU Education Sciences Research Ethics Committee

Original details: (22351930) C:\Users\22351930\Desktop\ETHICS APPROVAL LETTER OF STUDY.docm
8 November 2018

Current details: (22351930) M:\DSS1\8533\Monitoring and Reporting Cluster\Ethics\Certificates\Templates\Research Ethics Approval Letters\9.1.5.4.1 ES-REC Ethical Approval Letter.docm
5 December 2018

File reference: 9.1.5.4.2

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ADDENDUM B: PERMISSION LETTERS

University A

TO:	**Mr KJ Mabotja** **PhD Student – North West University**
FROM:	**Prof [redacted]** **HOD**
DATE:	**30 March 2022**
SUBJECT:	**PERMISSION TO CONDUCT RESEARCH**

Dear Samuel

Your letter dated 30 March 2022 requesting revised permission to conduct research and the initial permission letter granted on 19 April 2019 has reference.

Your initial request to conduct research with our fourth year BEd mathematics students was **granted** and is **reaffirmed** in light of your revised research project title (*The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa*). The initial condition that your research does not disturb or disrupt the teaching and learning activities in the mathematics classes still stands.

Furthermore, year 4 students have been repatriated and a blended format of tuition takes place with them. Kindly negotiate with the lecturers concerned, namely, [redacted]d [redacted] about the time frames and requirements for your research. All the best in your research and studies. For any further information, please contact my office on the details listed above.

Yours in Education,

[redacted]

UNIVERSITY [redacted]
DEPARTMENT OF MATHEMATICS, SCIENCE AND TECHNOLOGY
SCHOOL OF EDUCATION
30 MAR 2022
[redacted]
CAMPUS

University B

[redacted]

Priva[redacted]
South[redacted]

Tel: [redacted]
Web: [redacted]

Research Data Gatekeeper Committee

[redacted] RDGC PERMISSION GRANTED / DENIED LETTER

Based on the documentation provided by the researcher specified below, on 24/05/2019 the [redacted] Research Data Gatekeeper Committee [redacted]-RDGC) hereby grants permission for the specific project (as indicated below) to be conducted at the [redacted] University ([redacted].

Project title: The affordances of ethnomathematical perspectives in pre-service Mathemathics teacher education at selected universities in South Africa. **Project leader: Prof MS van der Walt** **Researcher/Project Team: KS Mabotja** **Ethics reference no: NWU-00792-18-A2** [redacted] **RDGC reference no:** [redacted]**-GK-2019-013** **Specific Conditions:** • The researcher is required to request an independent mediator to invite prospective participants to participate in the study at the end of the academic lesson. • The researcher should request participants to sign an NDA to ensure all participants are protected from any disclosure of their contribution to the study. **Approval date: 24/05/2019** **Expiry date: 23/05/2020**

General Conditions of Approval:

- The [redacted]-RDGC will not take the responsibility to recruit research participants or to gather data on behalf of the researcher. This committee can therefore not guarantee the participation of our relevant stakeholders.
- Any changes to the research protocol within the permission period (for a maximum of 1 year) must be communicated to the [redacted]-RDGC. Failure to do so will lead to withdrawal of the permission.
- The [redacted]-RDGC should be provided with a report or document in which the results of said project are disseminated.

Please note that under no circumstances will any personal information of possible research subjects be provided to the researcher by the [redacted]RDGC. The [redacted] complies with the Promotion of Access to Information Act 2 of 2000 (PAIA) as well as the Protection of Personal Information Act 4 of 2013 (POPI). For an application to access such information please contact Ms [redacted] for the relevant enquiry form or more information on how the [redacted] complies with PAIA and POPI.

The [redacted] RDGC would like to remain at your service as scientist and researcher, and wishes you well with your project. Please do not hesitate to contact the [redacted] RDGC for any further enquiries or requests for assistance

Yours sincerely

[redacted]

University C

[redacted]

OFFICE OF THE UNIVERSITY REGISTRAR

[redacted]
Kimberley
8300

Tuesday, 14 June 2022

Feedback on a research project submitted:

THE AFFORDANCES OF ETHNOMATHEMATICAL PERSPECTIVES IN PRE-SERVICE MATHEMATICS TEACHER EDUCATION AT SELECTED UNIVERSITIES IN SOUTH AFRICA – K Mabotja

Dear K Mabotja

The letter serves to inform you of the outcome of your research project which was re-submitted to Sol Plaatje University for ethics clearance.

Outcome: Ethics clearance was granted.

Sincerely,

[redacted]

UNIVERSITY REGISTRAR

ADDENDUM C: INFORMATION AND CONSENT FORM

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Private Bag X6001, Potchefstroom
South Africa 2520
Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Faculty of Education

(Self-Directed Learning)

Tel: 018 299 4656
Email: erna.greyling@nwu.ac.za

Date: 2019-2022

Dear Teacher Educator(s) and Student Teachers

PARTICIPANT INFORMATION AND CONSENT FORM

I herewith wish to request your consent to participate in this research, which involves teacher-educators and student teachers from three selected universities in South Africa. Before you give consent, please acquaint yourself with the information below.

The details of the research are as follows:

TITLE OF THE RESEARCH PROJECT:

The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa

PROJECT SUPERVISOR: Prof M Van der Walt
CO-SUPERVISOR: Prof JJJ de Beer
ADDRESS:

Mathematics Education
School for Science and Technology Education
Faculty of Education
North-West University (Potchefstroom Campus)
Private Bag X 6001
2520 Potchefstroom

South Africa
CONTACT NUMBER: 018 299 1854

MEMBER OF PROJECT TEAM PhD-Student: Mr KS Mabotja
ADDRESS:

314 Matamanyane
Koloti
Polokwane
0709
South Africa
CONTACT NUMBER: 0795370518

FACULTY OF EDUCATION RESEARCH ETHICS COMMITTEE
Contact person: Ms Erna Greyling, E-mail: Erna.Greyling@nwu.ac.za, Tel. (018) 299 4656.
This study has been approved by the Ethics committee of the Faculty of Education Sciences of the North-West University and will be conducted according to the ethical guidelines of this committee. Permission was also granted by NWU's RDGC

What is this research about?

The purpose of this research is:

- To investigate the affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa

Participants

- Teacher-educators
- Student-teachers
- Ethnomathematics expert

What is expected of you as participant?

Participate in audio/video-recorded focus-group interviews (Student-teachers)
Participate in audio-recorded semi-structured interviews (Teacher-educators)

Benefits to you as participant

The study intends to contribute to filling the existing gap of knowledge regarding the affordances of integration of ethnomathematical perspectives in pre-service mathematics teacher education at selected universities in South Africa. The findings of the study could be beneficial in informing universities to restructure, where necessary, the existing mathematics education and mathematics methodology courses for the integration of ethnomathematical perspectives in pre-service mathematics teacher education. Thus, it is the researcher's contention that South African universities training pre-service mathematics teachers would benefit from the knowledge formed in the study.

Risks involved for participants

Minimal risk

Confidentiality and protection of identity

Pseudonyms will be used.

Dissemination of findings

Findings in the form of a research report will be communicated to the participants once it has been assessed. If you have any further questions or enquiries regarding your participation in this research, please contact the researchers for more information.

<u>DECLARATION BY PARTICIPANT:</u>

By signing below, I agree to take part in a research study entitled:

The affordances of ethnomathematical perspectives in pre-service Mathematics teacher education at selected universities in South Africa

I declare that:

- I have read this information and consent form and understand what is expected of me in the research.
- I have had a chance to ask questions to the researcher and all my questions have been adequately answered.
- I understand that taking part in this study is voluntary and I have not been pressurised to take part.

- I may choose to leave the study at any time and will not be penalised or prejudiced in any way.
- I may be asked to leave the research process before it has finished, if the researcher feels it is in my best interests, or if I do not follow the research procedures, as agreed to.

Signed at (place)_____________________________on (date) ______/______/20____

______________________ ______________________

Signature of participant **Signature of witness**

ADDENDUM D: TEACHER EDUCATORS AND EXPERT SEMI-STRUCTURED INTERVIEW SCHEDULE

TEACHER EDUCATORS' SEMI-STRUCTURED INTERVIEW SCHEDULE

1. What is your understanding of ethnomathematics?
2. To what extent, if any, do you prepare/teach student teachers in ethnomathematical perspectives in mathematics education modules?
3. To what extent, if any, do mathematics and mathematics education methodology modules prepare/teach student teachers to contextualise mathematics?
4. In your view, is the mathematics teacher education programmes in your institution equipping student teachers with ethnomathematical perspectives?
5. In your view, what, if any, are the challenges you are likely to encounter towards incorporating ethnomathematical perspectives in mathematics education modules?
6. In your view, what are effective design principles for incorporation of ethnomathematical perspectives?
7. Which points of importance concerning ethnomathematical perspectives in pre-service teacher education - if any - would you like to add to the above?

EXPERT PARTICIPANT' SEMI-STRUCTURED INTERVIEW SCHEDULE

1. What is the importance (affordances) of ethnomathematics perspective in terms of mathematics education? (Or What are the affordances of ethnomathematics for school mathematics?)
2. What are some misconceptions about ethnomathematics?
3. What are the influences of these misconceptions on the criticism linked to ethnomathematics?
4. Why is there a need to prepare student teachers on ethnomathematics pedagogies?
5. In an era where calls are growing to decolonise curricula in South Africa and over the world, what contribution could ethnomathematics make to decolonise the curriculum?
6. What are the possibilities of integrating ethnomathematics in pre-service teacher education?
7. How can teacher educators integrate the contributions of diverse cultures into the pre-service teacher education? Could you please give an example(s)?
8. What are the potential challenges that could hinder successful integration of ethnomathematics in pre-service teacher education?

9. Which points of importance concerning ethnomathematical perspectives in preservice teacher education - if any - would you like to add to the above?

End

ADDENDUM E: STUDENT TEACHERS' PRE-INTERVENTION QUESTIONNAIRE

Private Bag X6001, Potchefstroom
South Africa 2520
Tel: 018 299-1111/2222
Web: http://www.nwu.ac.za

Faculty of Education

(Self-Directed Learning)

Tel: 018 299 4656
Email: erna.greyling@nwu.ac.za
March 2021

Dear student teacher,

This questionnaire intends to explore your understanding of mathematics and ethnomathematics pedagogies. Kindly note that the information you share will be treated confidentially. Thank you

Pre-ethnomathematics intervention workshop questionnaire

AGE:

18-25	26-30	31-40	40+

RACE:

African	Indian	White	Coloured	Other

LEVEL OF STUDY:

1st	2nd	3rd	4th

Programme:

Foundation phase	Intermediate phase	Senior phase	FET phase

1. Why did you choose to study teaching? What inspired you about teaching?

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2. How would you describe mathematics?

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3. In your view, how do learners learn mathematics?

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4. What is your understanding of contextualising mathematics through ethnomathematics?

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5. How would you describe ethnomathematics? Please explain what it means.

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6. Would you say that there is a place for ethnomathematics or indigenous knowledge (IK) in the mathematics classroom? Please choose and justify.

No - ethnomathematics or IK is pseudo-science and devoid of any substance. It does not belong in the Maths classroom.	Maybe some aspects of IK could be introduced in the Maths classroom.	Where applicable, indigenous knowledge should be brought in as a different perspective to the purely western view.	Definitely. Indigenous knowledge can make the learning of Mathematics much more meaningful.
1	**2**	**3**	**4**

(Adapted from, Cronje, 2015, p. 117)

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7. Do the methods of mathematics courses or modules prepare you to contextualise mathematics using ethnomathematics or Indigenous Knowledge? Please explain.

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8. Have you ever thought of using traditional games, beadwork, traditional buildings, cultural artefacts to contextualise mathematics? Why or why not? Please explain.

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8.1. What do you consider as advantages regarding the use of ethnomathematics pedagogies such as traditional games in the teaching and learning of mathematics?

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8.2. What do you consider as disadvantages regarding the use of ethnomathematics pedagogies such as traditional games in the teaching and learning of mathematics?

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9. Do you think ethnomathematics pedagogies (Indigenous Knowledge) can be valuable in the teaching and learning of mathematics? Why or why not? Please explain.

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10. What challenges do you anticipate in using ethnomathematics pedagogies in the teaching and learning of mathematics?

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ADDENDUM F: STUDENT TEACHERS' FOCUS GROUP INTERVIEW SCHEDULE

- What is your understanding of ethnomathematics?
- Do mathematics education methodology courses prepare you to contextualise mathematics in learners' cultural background? Please, elaborate.
- Do you think mathematics education methodology courses prepare you to incorporate ethnomathematics perspectives into the curriculum? Please, elaborate.
- In your view, what – if any - are the challenges in incorporating ethnomathematical perspectives in pre-service mathematics teacher education programmes?
- In your view, what will be, if any, the challenges towards incorporating ethnomathematical perspectives in your teaching of mathematics?
- Which points of importance concerning ethnomathematical perspectives in pre-service mathematics teacher education - if any - would you like to add to the above?

ADDENDUM G: TURNITIN SUMMARY

25876619:25876619Mabotja_KS.2022.pdf

ORIGINALITY REPORT

17%	16%	4%	2%
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