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Doctoral Thesis

**Development of knowledge and skills in initial mathematics teacher education
and early years of teaching career in Ghanaian Basic Schools**

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ABSTRACT

This study investigates the development of knowledge and skills in initial mathematics teacher education and the early years of teaching in Ghanaian basic schools. Despite significant curriculum reforms aimed at improving the quality of education, there has been limited research on how these changes impact early-grade mathematics teacher education. The study addresses this gap by exploring the content knowledge, pedagogical content knowledge, attitudes, and teaching efficacy beliefs of both pre-service and early career teachers in Ghana. Using a mixed-methods approach, the research collected quantitative and qualitative data through surveys and interviews. The participants included final-year pre-service teachers from four Colleges of Education and early career teachers from basic schools across Ghana. The findings revealed notable differences in the content knowledge and pedagogical approaches between pre-service and in-service teachers, with significant implications for improving teacher preparation programmes. Moreover, teacher attitudes toward mathematics and self-efficacy beliefs influenced their instructional practices and student outcomes. The study's results highlight the need for targeted interventions to enhance both content knowledge and pedagogical strategies in early mathematics teacher education. Recommendations are made for improving teacher education programmes to align more closely with Ghana's evolving educational reforms and the Global Proficiency Framework.

Keywords: Mathematics education, pedagogical content knowledge, teacher attitudes, early-grade teachers, pre-service teachers, in-service teachers.

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CHAPTER ONE – INTRODUCTION

Achieving Sustainable Development Goal 4.6 (SDG) predicts that, by 2030, all young people and a significant proportion of adults, regardless of gender, will attain proficiency in literacy and numeracy (UNESCO, 2021), this and the other 16 SDGs have become the hallmark of most educational systems. The integration of SDG 4.6 into educational systems worldwide has driven significant curriculum reforms, emphasising the importance of inclusive and equitable quality education. Schools are now adopting innovative teaching methods and ensuring that learning environments are safe and supportive for all students. This approach addresses learners' diverse needs and creates pathways for lifelong learning and personal development. In Ghana, the basic school curriculum has been undergoing several restructuring. The 2019 Ghanaian curriculum sought to establish a practical, relevant, and inclusive education system, arming learners with the essential skills and knowledge for personal growth while contributing to Ghana's development. The pre-tertiary education programme aimed to align with the Global Proficiency Framework and global best practices, prioritising skills like critical thinking and fostering skills development. This is a substantial departure from conventional educational approaches to equip learners for the demands of the contemporary world (MoE, 2019). Similarly, the provision of accessible and quality education for all to meet the country's needs is the core of the basic school curriculum; based on this, the new curriculum clearly outlines the learning areas to be taught, along with the methods of teaching and assessment. It also establishes core competencies and standards that students are expected to know, understand, and demonstrate as they advance through the curriculum (MoE, 2019). Many studies are concerned with the mathematical content knowledge of pre-service teachers (e.g., Depaepe et al., 2013; Mapolelo & Akinsola, 2015; Wu et al., 2018). The body of research examining teachers' competence and its impact on learners' academic performance encompasses numerous studies highlighting the significance of teacher education. These inquiries consistently reveal that individuals who have completed teacher education programmes show a higher level of preparedness for their teaching roles and can positively influence their students' academic achievements (Kennedy, 1997). In contrast, those who enter the teaching profession without a solid foundation in teacher education do not have these advantages (as referenced in (Darling-Hammond, 2003; Kennedy, 1997; Kennedy et

al., 2006; Laczko-Kerr & Berliner, 2003; Jong & Jackson, 2020). The issue of pedagogical training, subject matter expertise, and practical experience is crucial in Ghana (MoE, 2019).

Mathematics plays a central role within the educational curriculum, being a fundamental element across almost all countries as an integral part of the school programme (Keith, 2000). It is also recognised as an essential subject in its intrinsic significance due to its critical interconnections with diverse fields like the natural sciences, engineering, medicine, and the social sciences (Keith, 2000). Nonetheless, there has been a progressively growing concern regarding declining levels of students' achievements in mathematics, both on a national and international scale (Törner & Sriraman, 2006).

1.1 The Gap in Knowledge

According to studies by Eshun (2004) and Eshun-Famiyeh (2005), mathematics is seen as the most challenging subject in the school curriculum in Ghana. This general view has mirrored in students' performance over time. The National Education Assessment (NEA) administered from 2015 to 2022 showed that school-going children in Ghana struggled to read. Also, their performance in mathematics lagged the expected grade, with the percentages of basic three (3) and basic six (6) learners achieving proficiency in mathematics falling below 20 % (Fletcher, 2018; Hagan et al., 2020). Again, according to the Early-Grade Literacy and Mathematics Assessment (EGLMA) findings, only 6 % of primary school learners met the required benchmark for numeracy in Ghana (MoE, 2019).

Improving the teaching and learning of mathematics in Ghana has been an object of national interest for some time now (Aboagye & Yawson, 2020). In response to this demand, researchers, educators, and other stakeholders in the education sectors have channeled research into the issue and the way forward (e.g., Asiedu et al., 2004; Kraft, 1994; Mereku, 2004). Based on these empirical research and recommendations, the new mathematics curriculum for basic schools and Colleges of Education was introduced in 2019. Although several researchers (e.g., Eshun, 2004; Eshun-Famiyeh, 2005; Mereku, 2004; MoE, 2017) have explored mathematics classroom practices at the primary and senior secondary levels, not much work has been done on

developing knowledge and skills in initial mathematics teacher education at the early-grade level.

1.2 Aim of the Study

This research aims to examine the processes through which early-grade mathematics teachers in Ghana develop their professional knowledge and instructional skills during their initial teacher education and early teaching years. By focusing on both pre-service and early-career teachers, this study seeks to provide a comprehensive understanding of how content knowledge, pedagogical content knowledge, attitudes, beliefs, and teaching efficacy are cultivated and applied in real classroom contexts. Through this investigation, the research aims to uncover potential gaps and opportunities in teacher preparation programs and early professional experiences, offering actionable insights to improve teacher quality. Ultimately, the study aspires to inform policy and practical strategies for enhancing the quality of early-grade mathematics education in Ghana, thereby contributing to broader efforts to strengthen foundational mathematics learning and improve educational outcomes at the national level.

1.3 Research Questions

This study explores the content knowledge, pedagogical content knowledge, attitude towards mathematical teaching, beliefs and efficacy of pre-service and in-service early-grade teachers in Ghanaian Basic Schools.

To address these goals, the study is guided by a set of research questions that explore alignment, attitudes, and knowledge development. These questions are supported by published research outputs (references in the brackets after question), which provide further evidence and context for the findings:

RQ1: What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education in Ghana and the National Kindergarten Mathematics Curriculum? (Amusuglo & Jančařík, 2024a)

RQ2: How do Ghana's national kindergarten and Colleges of Education early-grade mathematics curricula align with the knowledge and skills outlined by the Global Proficiency Framework? (Amusuglo & Jančařík, 2024b).

RQ3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana? (Amusuglo et al., 2024)

RQ4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?

RQ5: What content and pedagogical content knowledge do early career teachers and pre-service early-grade teachers possess at the end of their College Education? (Amusuglo, 2024)

1.4 The Context of the Study: Ghana

This section summarises Ghana's education system to show the study's context. This describes the development of education in Ghana and the characteristics of Ghana's education system, beginning with a brief profile of Ghana with particular reference to the country's location, people and language. A brief overview of Ghana's education system concerning the development of Colleges of Education in Ghana is also presented in the study.

Ghana is located in West Africa, in South Saharan Africa. The population of Ghana is approximately 31 million and has a growth rate of 3% (GSS 2021). The 0 to 14-year-old dependency rate is 86%, and 45% of the population is under 15 years old. About 38% of the people live in urban areas; two-thirds primarily depend on agriculture for their livelihoods and income (GSS 2021). Ghana has borders to the north with Burkina Faso, west with Ivory Coast, east with Togo, and south with the Gulf of Guinea.

Ghana became independent from Britain on March 6, 1957. It has 16 administrative regions, each comprising metropolitan, municipal, and district areas (Ampiah & Akyeampong, 2002). Ghana has over 100 different dialects. Eleven of these dialects (Fanste, Ga, Twi, Ewe, Nzema, Gonja, Walewale, Kasem, Dagaare, Gonja, Dagbane) are accepted and used as kindergarten instruction medium. However, English is the official language from primary 1 to the university level (Ampiah & Akyeampong, 2002).

1.5 Basic Education in Ghana, Including Curriculum Matters

The education system in Ghana has undergone many reforms. Significantly, the structure and content of the 1987 reform reduced the number of years of pre-tertiary

education from 17 to 14 (MoE, 2017). The 2007 Education Reform Act included two years of early childhood education, kindergarten (from age 4). These two years have been formally included in the Free, Compulsory Universal Basic Education (FCUBE) policy, bringing the total number of years for pre-tertiary education to 14 (MoE, 2017).

The current structure of the education system in Ghana is as follows:

- Basic education level: eleven years – comprising kindergarten (two years), primary (six years) and junior high school (three years).
- Second cycle education: three years – consisting of senior high school, grammar and technical education, as well as other post-basic skills development programmes, including the National Apprenticeship Programme.
- Tertiary education level, pursuing a preferred programme at any of the universities, Colleges of Education (CoE), or technical universities, as well as undergraduate programmes with a minimum duration of three years for diploma programmes and four years for undergraduate degree courses (Buabeng et al., 2020).

Article 38 of Ghana's 1992 constitution mandates that all children of school age receive Free, Compulsory Universal Basic Education (FCUBE). The government established the foundation for attaining this goal in 1996. With the recent education reforms, formal Basic Education for all Ghanaian learners is from KG 1 to SHS 3 (Grade 12), and it is divided into five phases; namely, Phase 1: Foundation level comprising Kindergarten 1 & 2, Phase 2: Lower primary level made up of B1 to B3, Phase 3: Upper primary level from B4 to B6, Phase 4: Junior High School (JHS) level of B7 to B9, and Phase 5: Senior High School (SHS) level comprising SHS1- SHS3 (MoE, 2018).

The education system in Ghana is designed to be flexible, catering to students' diverse needs and preferences. Education at Phase 1 starts at age 4 with kindergarten (KG) education and links with Lower Primary education up to age 8. KG education predisposes children to conditions of formal schooling, giving them a mental attitude for learning in the future. The Upper Primary phase (age 9-11 years) attempts to lay a strong foundation for inquiry, creativity and innovation, and lifelong learning in general and to provide building blocks for higher levels of education (Anamuah-

Mensah Report, 2006). The third phase of basic education is the three-year Junior High School or JHS (age 12-15 years), which is lower secondary education and allows pupils to discover their interests, abilities, aptitudes and other potential. The final phase of basic education is the three-year SHS (age 15-18 years), which is upper secondary education and allows learners to specialise in the following programmes: Science, General Arts, Technical and Vocational, and Business. The SHS education is the platform that delivers an extensive scope of academic knowledge and skills required for further studies. In this context, after sitting and passing the West Africa Secondary School Certificate Examination (WASSCE) conducted by the West African Examination Council (WAEC), SHS graduates may gain direct admission into tertiary institutions like universities, colleges of education, nursing training, or undertaking a specialised programme like the Ghana Police Command, Ghana Institute of Journalism among others (MoE, 2019). The landmark curriculum reform in Ghana took place in 2017. The Government of Ghana entrusted the National Council for Curriculum and Assessment (NaCCA) with the task of reviewing the pre-tertiary curriculum in Ghana to align with international best practices (Apau, 2021). In September 2019, the Ghanaian government introduced a new curriculum into the basic education system. This major reform aimed to address the shortcomings of the previous curriculum, such as excessive content, the limitations of an objective-based approach, and the inadequacies of the assessment system in providing sufficient data to guide teaching and learning (Aboagye & Yawson, 2020). The new curriculum was specifically designed to enhance the development of skills in reading, writing, arithmetic, and creativity across the entire basic education system, focusing on improving mathematics teaching (Aboagye & Yawson, 2020).

Addai-Mununkum (2020) stated that the new curriculum is also designed to foster the development of 21st-century skills, including critical thinking and problem-solving, creativity and innovation, communication and collaboration, cultural identity and global citizenship, personal growth and leadership, as well as digital literacy. The revised curriculum emphasised the value of the "4Rs" Reading, Writing, Arithmetic, and Creativity as fundamental abilities necessary for lifelong learning and the country's advancement. The development of 21st-century abilities, including creativity, innovation, communication, teamwork, cultural identity, global citizenship,

critical thinking, personal growth, leadership, and digital literacy (MoE, 2019). In the context of Ghana's education system, 'basic education' encompasses the educational journey from kindergarten to the first year of Senior High School (MoE, 2019). Again, in Ghana, early-grade education starts from Kindergarten (KG) to grade three (3), and the curriculum emphasises that. KG prioritises the "4Rs". Incorporating 21st-century competencies like creativity is essential for preparing learners for life in the contemporary world, and creative children will likely solve complex tasks creatively, think outside the box, and communicate clearly (MoE, 2019). The curriculum suggests some activities that encourage experimentation, imagination, and exploration, which support creativity at the early-grade level. For instance, children's creative potential can be fostered by combining art, music, storytelling, and unstructured play (MoE, 2019).

If well implemented, teachers may offer a well-rounded learning experience that develops academic competency and cultivates critical abilities necessary for success in the twenty-first century by fusing creativity with the fundamental knowledge of Reading, Writing, Arithmetic and Creativity (MoE, 2019).

1.6 Teacher Education in Ghana with Emphasis on Early-grade Level

Ghana has worked on teacher education before independence (Antwi, 1992). In the Gold Coast era (Antwi, 1992; McWilliam & Kwamena-Poh, 1975; MoE 2018). According to Adegoke (2003) and Benneh (2006), the Ghanaian teacher education programme aims to provide a comprehensive teacher education programme through pre-and in-service training that will develop competent, committed, and dedicated teachers who will improve the quality of teaching and learning. Teacher Training Colleges (TTC), which are now referred to as Colleges of Education (CoE), originally, Teacher Training Colleges (TTC) offered a 2-year Post-Middle Certificate "B" program, followed by 4-year Post-Middle Certificate "A" and 2-year Post-Secondary Certificate "A" programs. In the 1980s, the 2-year post-secondary program was extended to a 3-year programme but ran alongside the 4-year certificate "A". Two legislation acts play an important role in teacher education in Ghana (Buabeng et al., 2020).

Firstly, the 2008 Education Act (Act 778) established the National Teacher Council (NTC) under Section 9. The NTC is responsible for developing and setting

professional practices and ethical standards for teaching, as well as registering and licensing individuals aspiring to join the teaching profession (Buabeng et al., 2020). Secondly, the Colleges of Education Act 847 was designed to elevate CoE into a tertiary institution. As a result of this legislation, starting in October 2018, the CoE was upgraded to four-year degree-granting institutions, eliminating the previous three-year diploma-awarding institutions. The introduction of the degree program allows future teachers to specialize in specific areas offered at the CoE, including the Early-grade programme, Primary Education programme, and Junior High School programme. As a result, prospective teachers will be licensed to teach within particular grade bands at the basic school level. Some expected benefits of this change include: 1) enabling prospective teachers to gain in-depth knowledge within a specific grade band, and 2) providing them with broad knowledge and experience in their chosen grade band or specialisation.

The CoE operates the semester system. Currently, each pre-service teacher goes through seven semesters in college and one semester of internship in a basic school. The courses offered at the CoE are comprised of content and methodology. The Colleges of Education (CoE) train teachers to teach from KG 1 to JHS 3 in Ghana. Following the upgrade, all CoEs in Ghana are now affiliated with five public universities namely, the University of Cape Coast, the University of Ghana, the University of Education, the University for Development Studies, and the Kwame Nkrumah University of Science and Technology.

The enactment of the Colleges of Education Act 2012, Act 847, legally supported their upgraded status. The CoE are now governed by the Ghana Tertiary Education Commission (GTEC), a government agency tasked with regulating tertiary education institutions in Ghana under Act 1023 (Asare & Nti, 2014).

CHAPTER TWO – LITERATURE REVIEW

Introduction

This chapter reviews the literature on research trends exploring the depth of the global proficiency framework, conceptualisations of teacher knowledge for teaching mathematics, subject-related knowledge for elementary teachers, mathematics proficiency, teacher attitudes, beliefs and efficacy that are needed to be developed in pre-service early-grade teachers.

Assessing teachers' knowledge base has been a challenging task due to various interpretations provided by researchers (e.g., Ball & Bass, 2000; Cochran & Jones, 1998; Grossman & Richert, 1988; Hill et al., 2008, Leinhardt & Smith, 1985; Ma, 1999; Shulman, 1986; Tamir, 1990; Thompson, 1984). Shulman (1986) introduced a model outlining seven types of teacher knowledge: general pedagogical knowledge, knowledge of student characteristics, educational contexts, purposes and values, content knowledge, curriculum knowledge, and pedagogical content knowledge (PCK). Later, he focused on three key areas: subject matter knowledge (SMK), PCK, and curriculum knowledge. According to Shulman, subject matter knowledge is the "amount and organisation of the knowledge per se in the teacher's mind" (Shulman, 1986, p. 9). Pedagogical content knowledge involves "ways of representing the subject which make it comprehensible to others"..."[it] also includes an understanding of what makes the learning of specific topics easy or difficult ..." (Shulman, 1986, p. 9). Knowledge of the curriculum includes understanding how topics are organised throughout the school year and other techniques for setting up a study plan for students using educational resources like textbooks. Even though Shulman's categories are not specific to mathematics teaching, many mathematics educators have used them as a foundation for their study. Similarly, Grossman and Richert (1988) characterise teacher knowledge as "a professional knowledge base encompassing both general pedagogical principles and skills, as well as subject matter expertise" (p. 54). Their study explored the essential knowledge for teaching, defining *teacher knowledge* as a blend of pedagogical principles and subject matter expertise. It highlights the importance of pedagogical content knowledge (Shulman, 1986), noting that teaching experience prompts teachers to reassess subject matter

from students' perspectives. This shift underscores the necessity for teacher education programmes to incorporate opportunities for teachers to deepen their understanding of subject matter about student learning, emphasising the critical role of pedagogical content knowledge. Thompson (1984) also suggested that teachers' use of mathematical knowledge in teaching might be influenced by their personal beliefs and perspectives regarding the subject.

Leinhardt and Smith (1985) distinguished two forms of teacher knowledge: lesson structure knowledge (LSK) and subject matter knowledge (SMK). This discourse was expanded when Shulman and his colleagues introduced the concept of pedagogical content knowledge (PCK) (Shulman, 1986). Ma (1999) added to this discourse by proposing the notion of a profound understanding of fundamental mathematics (PUFM), while Tamir (1990) built on Connelly and Clandinin's (1988) idea of teacher knowledge as 'an interaction between professional and personal knowledge' (p. 265).

Ball and her colleagues used Shulman's (1986) perspective as a starting point to investigate teaching in primary schools. They compiled a list of obstacles in teaching that require mathematical resources. Then, they examined the nature of such mathematical knowledge and skills and how they are held and applied in the classroom. In this way, they developed a practice-based portrait of Mathematical Knowledge for Teaching (MKT) includes common content knowledge (CCK), specialised content knowledge (SCK), knowledge of content and teaching (KCT), knowledge of content and students (KCS), knowledge of students and teaching (KST) and knowledge of curriculum and assessment (KCA). The authors believed that MKT is a type of professional mathematics knowledge distinct from what is required by other mathematically intense industries like engineering, physics, accounting, or carpentry. MKT was coined to describe the complex link between mathematics content understanding and instruction (Ball & Bass, 2000). They further explained that MKT is the domain of knowledge that a teacher uses during instruction. It is a resource teachers use to achieve a variety of teaching-related activities, such as tracking learners' mathematical thinking, evaluating the validity of learner-generated strategies, and making sense of a variety of learner-generated solution paths. It is the mathematical knowledge required for teaching duties. This indicates that knowledge for teaching mathematics is essential because it supports teachers' decisions about

which examples or representations to use, what connections to make during a lesson, and how to respond to learners' thinking.

Building on Shulman's idea, Hill et al., (2008) propose five distinct knowledge domains for teachers: personal, contextual, pedagogic, sociological, and social. This broader framework reflects the increasing diversity in classrooms and the complex interactions between teachers and their knowledge (Darling-Hammond, 2003; Ball et al., 2008).

Finally, a particularly relevant model for preschool and elementary teachers is the Knowledge Quartet by Rowland (2013). This model emphasises the differences between subject matter knowledge and teachers' pedagogical content knowledge and includes the term mathematical knowledge in teaching. The Knowledge Quartet model has the following dimensions: foundation, transformation, connection, and contingency. The foundation considers the teachers' knowledge about pupils' possible errors, misconceptions, and mathematical terminology. Transformation is related to how teachers transform their knowledge using demonstrations, examples, and representations to make it accessible to pupils. Connection refers to all possible connections among mathematics topics and the order of examples or tasks throughout instruction. Contingency is the teachers' ability to respond to unexpected moments by thinking "on their feet" (Rowland et al., 2009, p. 135). Edwards and Ogden (1998) also studied curriculum subject knowledge, focusing on how subject matter interacts with curriculum requirements. They examined this interaction through a case study involving teacher-mentors and student-teachers, particularly how subject matter knowledge evolves in teaching multiple subjects in primary education. Their findings underscore the importance of teachers translating subject knowledge into tasks that aid student learning, highlighting the dynamic nature of teacher subject matter knowledge. The study emphasises implications for teacher education, stressing the significance of comprehending subject matter within the framework of pedagogical demands and student learning objectives. In Ghana, issues of pedagogical training, subject matter expertise and practical experience are particularly significant following the curriculum review (MoE, 2019).

Content knowledge is the foundation upon which effective mathematics instruction is built. Thurm et al., 2024 described it as teachers' understanding of subject matter,

including concepts, structures, and procedures. Teachers with robust content knowledge can present mathematical concepts more effectively, identify common misconceptions, and provide in-depth explanations. Blömeke et al., (2008) and Kahan et al., (2003) found that teachers with strong content knowledge are better equipped to offer multiple solution strategies and anticipate student difficulties. (Ball & Phelps 2008). further refined the concept of PCK by focusing on teachers' ability to interpret how students understand mathematical concepts, requiring continuous adaptation throughout lessons. Again, Ball and Bass (2000) emphasised that Mathematical Knowledge for Teaching (MKT) is a specialised form of professional knowledge, distinct from other fields.

Hill-Jackson and Craig (2023) expanded on the development of PCK, suggesting that collaboration between teacher educators and pre-service teachers helps to build teaching knowledge and reiterated that effective teaching involves making students' mathematical thinking visible, which requires teachers to adapt dynamically during instruction. The development of PCK involves planning, evaluating resources, representing key ideas, selecting strategies, and differentiating materials based on learners' needs (La Velle & Newman, 2021; Newton et al., 2012).

The Knowledge Quartet by Rowland and Turner (2007) is particularly relevant for preschool and elementary teachers. It distinguishes between subject matter knowledge and pedagogical content knowledge, organising mathematical knowledge through four dimensions: foundation, transformation, connection, and contingency. These dimensions help teachers adapt their knowledge in classroom practice, anticipate student errors, and create deeper connections between topics (Rowland et al., 2009).

2.1 Subject-Related Knowledge for Preschool and Elementary Teachers

Effective teaching methodologies and subject-related knowledge are critical in early childhood and elementary education (MoE, 2019) and require distinct forms of subject-related knowledge, specifically tailored to young children. Elementary mathematics instruction requires knowledge across various mathematical topics, such as numbers, operations, and algebra, as well as understanding learners (Rowland & Ruthven, 2010). However, research on mathematics knowledge for preschool and elementary teachers is limited.

Ma's (1999) comparative study of American and Chinese elementary teachers revealed significant differences in their mathematical understanding, particularly regarding subtraction, multiplication, division of fractions, and geometry. Chinese teachers exhibited a higher level of content understanding and were more effective in teaching strategies due to a strong foundation in both procedural and conceptual knowledge.

Turner's (2008) longitudinal study, which followed 12 elementary teachers over three years, used the Knowledge Quartet framework to provide structured feedback on their mathematics lessons. Initially, the teachers selected representations based on visual appeal rather than conceptual clarity, but as they engaged with the framework, they improved their pedagogical content knowledge, focusing more on deepening students' conceptual understanding.

Similarly, Livy, et al., (2017) investigate the development of pre-service teachers' knowledge for teaching in the early years, specifically focusing on the selection and sequencing of mathematical content. The authors explore how pre-service teachers make decisions about which concepts to teach and the order in which to present them. The study highlights the importance of helping pre-service teachers develop a strong understanding of the progression of mathematical concepts, enabling them to teach effectively in the early years. The authors emphasise the need for teacher education programs to provide clear guidance and support in selecting and sequencing content to ensure that pre-service teachers are well-prepared for teaching young learners. Klibanoff et al. (2006) investigate the impact of teacher "mathematics talk" on preschool children's mathematical knowledge, highlighting the critical role of early mathematical discourse in shaping children's numerical and spatial understanding. The study found that the frequency and quality of teachers' mathematical language significantly influenced children's mathematical growth, emphasising that exposure to explicit mathematical discussions enhances conceptual understanding. The authors argue that teacher-initiated conversations about numbers, operations, and spatial relations contribute to children's early mathematical development, reinforcing the importance of pedagogical strategies that incorporate structured math talk in early childhood classrooms. This study aligns with research on pedagogical content knowledge (PCK) by demonstrating how teachers' mathematical discourse mediates children's learning experiences and supports their cognitive development in

mathematics. Consequently, the findings underscore the necessity for teacher training programs to equip educators with skills to engage young learners in rich mathematical conversations, fostering deeper comprehension and long-term achievement in mathematics. Similarly, Lee (2010) explores kindergarten teachers' pedagogical content knowledge (PCK) of mathematics, focusing on how teachers' understanding of both mathematics content and effective instructional strategies influences their teaching practices and students' learning outcomes. The study reveals that while many kindergarten teachers possess strong subject matter knowledge (SMK), their PCK specifically their ability to adapt mathematical concepts for young learners varies widely. Teachers who demonstrated high levels of PCK were able to link mathematical ideas with developmentally appropriate teaching strategies, providing clearer explanations and fostering a supportive learning environment for young children. Lee emphasises the importance of understanding the mathematics content and knowing how to present it in a way that aligns with young children's cognitive development and learning needs. This research contributes to the broader literature on teacher knowledge by illustrating that effective early mathematics teaching requires a blend of mathematical expertise, pedagogical techniques, and an understanding of child development. The study suggests that professional development programs should focus on enhancing kindergarten teachers' PCK, equipping them with the tools to effectively teach mathematics to young children, thereby improving early mathematical achievement. Another study by Taşkin and Sezer (2022) showed that preschool teachers' attitudes towards mathematical pedagogical content knowledge (PCK), mathematics, and mathematics teaching, shedding light on how these attitudes shape their instructional practices and engagement with early mathematics education. The study reveals that preschool teachers who exhibit positive attitudes toward mathematics and its teaching are more likely to integrate effective teaching strategies that promote mathematical understanding among young learners. The research highlights that teachers' PCK, which includes both knowledge of mathematics content and the ability to teach it in a child-centered, developmentally appropriate manner, is crucial in fostering a positive learning environment for preschoolers. Teachers with a strong belief in the importance of mathematics education tend to demonstrate more confidence and creativity in their teaching, using engaging methods to introduce mathematical concepts. On the other hand, those with less positive attitudes may struggle with implementing effective mathematical instruction. The authors suggest

that teacher education programs and professional development opportunities should focus not only on enhancing mathematical content knowledge but also on cultivating positive attitudes toward mathematics and teaching it, ultimately improving early childhood education outcomes.

Professional development is essential for enhancing teachers' knowledge and instructional quality. Structured programmes focusing on content and pedagogy yield significant improvements in teaching (Darling-Hammond et al., 2018). Collaborative learning communities, mentorship programmes and training sessions deepen teachers' knowledge (Evans, 2014; Mewborn, 2003).

Reflective practice is another key component of professional growth. Minott (2010) emphasised that reflective practices allow teachers to identify areas for improvement, leading to better student outcomes.

2.2 The Need for the Global Proficiency Framework for Mathematics

In mathematics education, the proficiency of both students and teachers plays an important role in shaping learning outcomes and achieving educational goals. Hence, the National Council of Teachers of Mathematics (NCTM) expresses mathematics proficiency as "the ability to use mathematical concepts, procedures, and strategies to solve a wide range of mathematical problems and to explain and justify one's thinking" (NCTM, 2000, p. 5 cited in Evans et al., 2001). By this assertion, mathematics proficiency involves procedural fluency (the ability to perform mathematical procedures accurately and efficiently) and conceptual understanding (the ability to understand and explain mathematical concepts and their relationships). While Kilpatrick (2001) defined it as the application of knowledge and expertise in mathematics, the author further argued that mathematics proficiency is not an absolute state but a developmental process that develops over time and is characterised by factors like instruction, practice, motivation, and cultural and contextual factors. Therefore, it is multi-dimensional and covers a range of knowledge, skills, and dispositions. Teachers can employ Kilpatrick's concept of mathematics proficiency to design engaging curricula that emphasise skill development and foster positive attitudes toward mathematics. This approach enables the evaluation of students' mathematical competency, considering factors beyond

academic performance, and guides instruction by emphasising the importance of employing diverse teaching strategies, providing ample practice opportunities, and creating an engaging classroom atmosphere to enhance students' mathematical proficiency.

Attaining Sustainable Development Goal 4 (SDG) has emerged as a central objective for many educational systems worldwide, sparking ongoing deliberations on effective strategies for its realisation. The Global Proficiency Framework for Mathematics (GPF), also known simply as the GPF or the framework, has been developed to respond to these discussions. This framework delineates the universal minimum proficiency levels expected of students upon completing each grade level, from grade one to grade nine. The GPF was developed by mathematics educators, curriculum experts, and psychometricians with extensive experience in developing and implementing mathematics programmes across various countries and contexts (Ovsyannikova, 2019).

The development process was an extensive one. It began in October 2018 with the development of the Global Content Framework of Reference for Mathematics by the UNESCO International Bureau for Education (UNESCO, 2021). The primary objective of the framework is to establish a universal benchmark for worldwide reporting and interpretation of mathematics assessments conducted at national, regional, and international levels; it has shown to be an instrument for countries and organisations aiming to create new assessments that measure progress based on global standards from grade one to grade nine (UNESCO, 2021). However, the framework allows nations to evaluate how well their standards, curriculum, evaluations, teacher preparation programmes, teaching resources, and classroom procedures correspond with the minimal expectations the framework sets for students. Deep discussions on the nature of comprehensive evaluations and the quality of teaching and learning have resulted from using the framework for these new goals (UNESCO, 2021).

Countries, including Ghana, could benefit from the GPF by having standards, curricula, assessments, and teaching methods all aligned to a single international framework (UNESCO, 2021). This could improve the equity and quality of mathematics education. However, it is essential to consider several challenges and limitations. Nevertheless, the differences in economic resources, teaching capacity, cultural norms and communication surrounding education among nations make

reaching a consensus on global standards challenging (Kamens & McNeely, 2010). Therefore, it will be difficult for certain developing nations to meet the GPF goals with substantial investments in infrastructure and educational change (Walker, 2021).

In addition, the emphasis on uniform results may compromise local curriculum autonomy and adaptability to suit changing circumstances. The sociocultural learning environment shapes situational dimensions of mathematical proficiency (Walker, 2021). Therefore, the GPF's universal measures should be thoroughly verified to guarantee equitable evaluation across all groups. However, the framework provides countries with the perspective to assess the alignment between their standards, curricula, assessments, teacher training programmes, instructional materials, classroom practices, and the minimum expectations set by the framework for learners. Utilising the framework for these additional purposes has led to profound reflections on the quality of teaching and learning and the nature of comprehensive assessments (UNESCO, 2021).

Curriculum materials are among the most important influences on teachers' instruction. Because we are living in a globally competitive world, national curricula must be compared with international standards to find out how they are aligned with international standards. Some studies have been done in the past to compare some country's specific curricula to international standards. (For example, Balagtas et al., 2019) conducted a study to compare the Philippine 2016 K–12 Mathematics Curriculum with The International Mathematics and Science Study (TIMSS) 2015 Grade 4 Mathematics Assessment Framework. The study showed that K–12 Mathematics Grade 4 is more aligned with the TIMSS 2015 assessment framework than mathematics Grade 8, Science Grade 4, and Science Grade 8 through curricular mapping of experts on the skills in the two documents. The alignment of eighth-grade mathematics instruction in the United States with the National Council of Teaching of Mathematics (NCTM) Standards was also the focus of research by Jacobs et al. (2006). The study's findings indicated that most of the eighth-grade teachers who took part in it said in questionnaire responses that they were familiar with current ideas and had a specific understanding of the NCTM. However, the visual produced by the video studies revealed that classroom practices were not adhered to in accordance with NCTM-established process and principles standard for Grades 6 to 8.

While the previous studies focused on TIMSS and NCTM, it appears that there is an apparent lack of literature that focuses on evaluating the alignment of country-specific early-grade mathematics curricula to a global framework for mathematics. It is important to focus studies on the GPF because it is a globally recognised framework that provides nations and international assessments with organisations a common scale for reporting progress on indicator 4.1.1 of the SDGs. This framework takes the form of a common definition of the minimum required knowledge and skills that students must demonstrate at critical points in their learning trajectory (see Table 1).

Table 1: Framework Descriptors

Global Minimum Proficiency	Definition
Below Partially Meets Global Minimum Proficiency	Learners lack the most basic knowledge and skills. As a result, they generally cannot complete the most basic grade-level tasks.
Partially Meets Global Minimum Proficiency	Learners have limited knowledge and skills. As a result, they can partially complete basic grade-level tasks.
Meets Global Minimum Proficiency	Learners have developed sufficient knowledge and skills. As a result, they can complete the most basic grade-level tasks.
Exceeds Global Minimum Proficiency	Learners have developed superior knowledge and skills. As a result, they can complete complex grade-level tasks.

Source (UNESCO, 2021)

2.3 Teacher Attitude, Beliefs, and Efficacy

Researchers agree that teaching effectiveness is influenced not only by teachers' knowledge but also by their attitudes, beliefs, and self-efficacy (Chan & Elliot, 2004). Han and Carpenter (2014) define attitude as a combination of cognitive, affective, and behavioural responses that individuals exhibit towards an object or environment based on their feelings or interests. The cognitive component of attitude refers to individuals' thoughts about mathematics, while the affective component pertains to the emotions associated with learning mathematics (Mensah et al., 2013; MoE, 2012).

Attitudes are relatively stable constructs that change gradually over time (Hannula, 2012).

Mensah et al. (2013) argued that the relationship between teaching and learning mathematics through affective variables is multifaceted but significant in mathematics education. Students with a positive attitude and confidence in their mathematical abilities will likely succeed. Studies showed a correlation between attitudes and academic achievement; students with positive attitudes toward mathematics performed better academically (Nicolaidou & Philippou, 2003; Mazana et al., 2019).

For pre-service and in-service primary school teachers who are often not mathematics specialists, affective factors such as attitudes towards mathematics and its teaching are particularly important. Their attitudes, often negative, impact their teaching effectiveness and, consequently, student outcomes (Tapia & Marsh, 2004). Negative attitudes can hinder their ability to become effective mathematics teachers, making it crucial to evaluate and implement training programs that address these attitudes and encourage positive change where necessary (Bursal & Paznokas, 2006; Lutovac & Kaasila, 2014; Lamb & Stinson 2018 and Perry & Staiger, 2018). Factors such as class size, hands-on experiments, and the depth of concepts have been identified as contributors to positive attitudes among pre-service primary teachers.

Again, Tapia and March (2004) distinguish the following components of the attitude toward mathematics construct: Mathematics Anxiety, Confidence in Learning Mathematics, Value of Mathematics, Mathematics Enjoyment and Motivation for Learning Mathematics. Each will be presented separately.

2.3.1 Mathematics Anxiety among Learners

Mathematics anxiety refers to emotions of anxiety or fear that hinder the ability to work with numbers and solve mathematical problems. Specifically, it encompasses the sensation of apprehension or stress related to learning mathematical concepts, which can hinder an individual's ability to engage in mathematical activities (Ashcraft, 2002). Recognising and identifying instances of mathematics anxiety in children is crucial to prevent the development of fear that could detrimentally influence their mathematical learning experience (Aarnos & Perkkilä, 2012). The authors assert that the intensity of anxiety can vary, falling into categories of high, moderate or low. When anxiety levels are low or moderate, learners tend to concentrate on

mathematical calculations and problem-solving. In pre-service and practising teachers' contexts, mathematics anxiety can also significantly affect their engagement with the subject and their ability to teach mathematics effectively. High levels of anxiety can create barriers to their professional development, leading to negative self-perceptions of their mathematical abilities, which may impact their teaching practices and interactions with students. Hembree (1990) conducted a comprehensive meta-analysis highlighting mathematics anxiety's effects on achievement and engagement with the subject. His findings revealed that high levels of anxiety significantly hinder performance and create a negative perception of mathematics, which could extend into teaching practices. Teachers who experience high anxiety may avoid specific mathematical topics or exhibit less confidence in their teaching, potentially affecting their students' learning outcomes.

Similarly, Aldrup and Lüdtke (2020) found a correlation between mathematics anxiety and performance, stating that high mathematics anxiety leads to low achievement. Teachers with high anxiety may also inadvertently transmit their fear and apprehension about mathematics to their students, creating a cycle that reinforces the negative attitudes toward the subject. Therefore, addressing mathematics anxiety in learners and teachers is essential to promoting a more positive and effective mathematical learning environment.

2.3.2 Confidence in Learning Mathematics

Confidence entails a favourable mindset exhibited by individuals who believe in their capabilities and have the potential to cultivate a positive perception of their environment (Suhardita, 2011). This has to do with believing in one's competencies and being fully conscious of the capacity one possesses to put these competencies into practice effectively. Similarly, students with robust confidence are more likely to realise their latent potential as an inherent capability that significantly influences their academic performance. This notion aligns with Stankov (2013) who emphasised the significance of confidence in students' successful engagement with mathematics learning. However, Çiftçi and Yildiz (2019) reaffirm that in the context of learning mathematics, students with high confidence demonstrate elevated motivation and enthusiasm towards studying mathematics, consequently optimising their achievement

in the subject. Studies have shown a positive association between confidence in learning mathematics and mathematics achievements.

2.3.3 Mathematics Enjoyment

According to Ainley and Ainley (2011), enjoyment in mathematics refers to the positive emotional experiences and pleasures individuals derive from engaging with mathematical activities and concepts. It encompasses a sense of interest, satisfaction and engagement while working on mathematical problems or exploring mathematical ideas. Enjoyment represents the positive emotional response and satisfaction that students experience when interacting with mathematical activities.

In the context of pre-service and in-service teachers, enjoyment in mathematics is equally important, as it can influence their attitude toward teaching and their ability to engage students in the subject effectively. Teachers who find joy in mathematics are more likely to foster a positive learning environment, which can be contagious to students. Conversely, when teachers experience low levels of enjoyment or even anxiety related to mathematics, it can affect their teaching practices and their students' learning experiences. Therefore, both enjoyment and anxiety are critical factors in shaping the experiences of teachers and learners in mathematics. Teachers who enjoy mathematics tend to approach the subject with more enthusiasm and confidence, which can lead to better outcomes for their students. Recognising the role of enjoyment in both pre-service and in-service teachers is essential for promoting a positive attitude toward mathematics and enhancing teaching effectiveness.

2.3.4 Value of Mathematics

Schoenfeld (2002) discusses the significance of students' attitudes and values toward mathematics education, arguing that their beliefs about mathematics play a critical role in their learning experiences and outcomes. Specifically, when students perceive mathematics as important and useful in their daily lives and future careers, they are likely to engage actively with the subject, persist in problem-solving, and seek connections between mathematical concepts and real-world situations. Conversely, negative attitudes or perceptions of mathematics can lead to disengagement and hinder learning progress. Schoenfeld emphasises that fostering a positive valuation of

mathematics among students is essential for promoting their active participation and success in the subject.

2.3.5 Motivation in Learning Mathematics

Ryan and Deci (2000) propose that students are more motivated when they experience a sense of autonomy, competence, and relatedness in their learning environments. This framework, known as Self-Determination Theory (SDT), emphasises that the drive to engage with and persist in mathematical tasks is significantly influenced by these three psychological needs. In the context of mathematics education, autonomy refers to students feeling a sense of control over their learning processes, competence pertains to their beliefs in their ability to successfully perform mathematical tasks, and relatedness involves feeling connected to teachers and peers within the learning community.

According to Ryan and Deci (2000), when students perceive themselves as capable (competent) and understand the relevance of mathematical concepts to their lives (autonomy), they are more likely to develop intrinsic motivation. This intrinsic motivation drives them to engage deeply with mathematical problems, persist through challenges, and seek meaningful connections between mathematics and real-world applications. Furthermore, fostering a supportive and collaborative classroom environment (relatedness) enhances students' motivation by making them feel valued and understood.

Supporting this theoretical framework, Moyano et al. (2020) found that high levels of intrinsic motivation are predictors of mathematics achievement. Their study demonstrated that students who are intrinsically motivated exhibit greater enthusiasm, better problem-solving skills, and higher academic performance in mathematics. This positive correlation underscores the importance of creating educational strategies that nurture autonomy, competence, and relatedness to boost students' intrinsic motivation and, consequently, their success in mathematics.

2.4 Elementary School Teachers' Self-Efficacy in Mathematics Teaching

Bandura (1997) asserts that self-efficacy is an individual's belief in their capability to organise and execute the actions required to manage prospective situations, which

plays a pivotal role in teaching effectiveness. High self-efficacy drives teachers to undertake greater efforts, while low self-efficacy may lead to inactivity and non-performance. Research by Pajares (2006) and Zeldin et al. (2008) demonstrates that pre-service teachers with high levels of self-efficacy are more motivated to learn and persist when faced with challenges.

Mathematics self-efficacy refers to individuals' beliefs or perceptions regarding their abilities in mathematics (Bandura, 1997; Ferla et al, 2015). It is closely tied to confidence in solving mathematical problems. Gavora (2010) and Schillinger (2021) emphasise that high mathematics self-efficacy enhances teachers' ability to implement effective teaching strategies, fostering student engagement and achievement.

According to Bandura (1986), self-efficacy consists of two dimensions: efficacy expectations (beliefs in one's ability to execute behaviours successfully) and outcome expectancies (beliefs that specific behaviours will result in desired outcomes). Enochs et al., (2000) further categorised teacher beliefs into two dimensions: personal teaching efficacy (beliefs in one's skills and abilities to be an effective teacher) and teaching outcome expectancy (beliefs that effective teaching can result in student learning regardless of external factors).

Gavora (2010) posits that differences in teacher effectiveness may largely stem from variations in teaching self-efficacy. Teachers with high self-efficacy often exhibit positive teaching behaviors, such as embracing new ideas and innovations (Henson, 2001; Pajares & Miller, 1995), managing classrooms effectively, and providing more attention to students with low abilities (Brouwers & Tomic, 2003; Ross & Bruce, 2007). In line with this, Guskey and Passaro (1994) conducted a study on teacher efficacy, focusing on its construct dimensions and how they influence teachers' perceptions of their ability to affect student outcomes. They identified key dimensions of teacher efficacy, including personal teaching competence and the perceived impact of teaching strategies on student achievement. Their research found that teachers with higher efficacy beliefs were more likely to engage in innovative teaching practices and persist through challenges. This study underscores the importance of teacher efficacy in shaping instructional behaviors and fostering positive educational outcomes. The findings highlight teacher efficacy as a critical factor in improving both teaching effectiveness and student learning. These teachers demonstrate a greater interest in and commitment to teaching, which contributes to higher retention rates in

the profession (Tschannen-Moran & Woolfolk Hoy, 2001). Takunyaci and Takunyaci (2014) investigated preschool teachers' personal mathematics teaching efficacy and outcome expectancy using the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI). Their study revealed that teachers generally held low efficacy beliefs in teaching mathematics, although efficacy increased among those with more teaching experience. Similarly, Todd Brown (2005) explored the impact of teacher efficacy and beliefs on instructional practices among early childhood teachers. While teacher efficacy did not directly correlate with observed instructional practices, it significantly related to teacher beliefs. Teachers with higher efficacy value mathematics more and were motivated to create engaging and effective learning environments (Gibson & Dembo, 1984; Wheatley, 2002).

Studies consistently show a positive association between confidence in learning mathematics and mathematics achievement (Çiftçi & Yildiz, 2019; Yaniawati et al., 2020). Teachers with strong self-efficacy in teaching mathematics are more inclined to use strategies that foster student engagement and enhance mathematical reasoning. This creates a growth-oriented classroom environment where students feel encouraged to take risks and explore mathematical ideas (Hoy, 2000). Research consistently highlights that pre-service teachers' self-efficacy plays an important role in shaping their teaching practices, particularly in fostering student motivation and problem-solving skills (Tschannen-Moran & Hoy, 2001). Teachers with high self-efficacy are likely to adopt innovative instructional strategies and create a growth-oriented classroom environment where students are encouraged to take risks and explore mathematical concepts. This contrasts with pre-service teachers who have low self-efficacy, as they may resort to traditional, procedural teaching methods that limit students' opportunities to develop a deep, conceptual understanding of mathematics. The way pre-service teachers perceive their capabilities directly influences the quality of learning experiences they provide, thereby impacting both student confidence and achievement (Jerrim et al., 2023).

Promoting high self-efficacy among mathematics teachers, including pre-service teachers, is essential for improving instructional practices and enhancing student outcomes. Research shows that professional development programmes focused on building teachers' confidence in both content knowledge and pedagogical skills can significantly increase their self-efficacy (Ross & Bruce, 2007). For pre-service

teachers, developing high self-efficacy during their training is particularly critical, as it helps shape their beliefs and approaches to teaching once they enter the classroom. For example, a study by (Takunyaci & Takunyaci, 2014) found that pre-service teachers who participated in a professional development workshop on teaching strategies for struggling learners reported higher self-efficacy and subsequently implemented more engaging and supportive teaching methods. Teachers' attitudes, beliefs, and self-efficacy are widely recognised as influential factors in mathematics education. Ahmad and Aziz (2009, p.19) argue that teachers' perceptions of their teaching and learning environments play a crucial role in shaping their decisions on managing classroom dynamics. Additionally, the teacher's perception of their teaching style is essential in comprehending how they deliver the subject matter. These beliefs, which include views on mathematics, teaching, learning, and students' abilities, profoundly shape their instructional practices and, ultimately, student success. When both pre-service and in-service teachers hold positive beliefs about their teaching abilities and engage in practices that foster student growth, they are more likely to create supportive classroom environments conducive to learning. For instance, a pre-service teacher with high self-efficacy might encourage a collaborative approach to problem-solving, allowing students to explore mathematical concepts in depth and fostering a deeper understanding of the material.

Conversely, low self-efficacy may contribute to a cycle of negative teaching attitudes, where teachers rely on outdated methods that fail to engage students effectively. This is especially concerning for pre-service teachers, as their early experiences and beliefs about teaching can shape their long-term teaching practices. For example, a pre-service teacher with low self-efficacy might resort to rote memorisation and direct instruction, limiting students' ability to apply mathematical concepts to real-world problems (Bandura 2000; Bates & Kim 2011). Therefore, addressing these negative attitudes and enhancing self-efficacy through targeted training and a supportive educational environment is critical. Programmes that encourage pre-service teachers to reflect on their beliefs and teaching practices not only improve their self-efficacy but also contribute to the overall quality of mathematics education, particularly in early childhood settings (Tschannen-Moran & Woolfolk Hoy, 2007).

One such programme, a reflective teaching practice seminar, allowed pre-service teachers to analyse their own teaching experiences and identify areas for improvement.

By fostering such an environment, we can cultivate confident, competent mathematics teachers both pre-service and in-service who are better equipped to support student learning and success.

CHAPTER THREE – METHODOLOGY

Introduction

This chapter outlines the methodology for addressing the five research questions guiding this study. It provides a detailed explanation of the qualitative data analysis, quantitative data analysis, the mixed-methods approach, and the instruments used, as well as their application in addressing these research questions. Additionally, it explains the procedures for both qualitative and quantitative data collection, the instruments used, and their relevance to the research questions. Data for this study were collected using three methods: content or document analysis, survey questionnaires administered to pre-service early-grade teachers and in-service teachers in the early years of their teaching careers, and interviews conducted with both categories of teachers. The research questions are as follows:

RQ1: What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education in Ghana and the National Kindergarten Mathematics Curriculum?

RQ2: How do Ghana's national kindergarten and Colleges of Education early-grade mathematics curricula align with the knowledge and skills outlined by the Global Proficiency Framework?

RQ3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana?

RQ4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?

RQ5: What content and pedagogical content knowledge do early career teachers and pre-service early-grade teachers possess at the end of their College Education?

3.1 Research Design Matrix

Combining the analysis of quantitative and qualitative data techniques enhances comprehension of the research problem and questions beyond what a singular approach can offer (Creswell & Clark, 2007). This mixed-methods approach was used to address distinct yet interconnected research questions.

Table 2 below summarises the relationship between the research questions, the type of data collected, the instruments used, and the concepts addressed.

Table 2: Research Design Matrix

Research Questions	Type of data	Instrument(s)	Concepts
RQ 1: What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education in Ghana and the National Kindergarten Mathematics Curriculum? (Amusuglo & Jančařík, 2024a).	Qualitative	Curriculum Material (CoE) and national early-grade curriculum)	Intended Curriculum
RQ2: How does Ghana's national kindergarten and Colleges of Education early-grade mathematics curricula align with the knowledge and skills outlined by the Global Proficiency framework? (Amusuglo & Jančařík, 2024b).	Qualitative	Curriculum materials (GPF, CoE, and National early-grade curriculum	Key knowledge and skills by grade level in GPF (P1-3).
RQ 3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana? (Amusuglo et al., 2024).	Quantitative	The Attitudes Towards Mathematics Inventory (ATMI)	beliefs and efficacy
RQ 4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?	Quantitative	Mathematics Teaching Efficacy Beliefs Instrument (MTEBI)	Attitude towards mathematics beliefs and efficacy
RQ 5: What content knowledge and pedagogical content knowledge do early career teachers and pre-service grade teachers possess at the end of their College Education? (Amusuglo, 2024)	Quantitative	Items from Mathematics Pedagogical Content Knowledge Instrument (MPCKI) and National Standard Test (NST)	Pedagogical content knowledge
	Qualitative	Semi- structured interview.	

3.2 Participants

This study's participants included final-year pre-service teachers enrolled in early-grade programmes across ten selected Colleges of Education in Ghana, as well as in-service early-grade teachers in their first five years of teaching. The in-service teachers were actively teaching in four municipal districts across two regions of Ghana: The Central and the Western regions.

The selection of participants was guided by Ewing and Manuel's (2005) and Cohen and Morrison's (2000) classification of teachers within their first five years of teaching as early career teachers. The Central and Western regions were chosen for their representation of both rural and urban districts, as well as their convenience for the study. These regions together host seven Colleges of Education, with twenty-two districts in the Central region and seventeen districts in the Western region

Table 3: Final year Pre-service ECE teachers in 4 Colleges of Education in Ghana

Name of College	Region	Number of early-grade pre-service teachers.
CoE 1	Central region	87
CoE 2	Central region	79
CoE 3	Western region	89
CoE 4	Western region	87
Total		344

Source: National Teaching Council (2022)

Table 4: Sample of early-grade teachers from Central and Western regions.

Educational circuits	Number of schools	Number of early-grade teachers
Central region		
Circuit A	14	8
Circuit B	10	11
Circuit C	18	12
Circuit D	15	9

Western region		
Circuit A	10	13
Circuit B	17	7
Circuit C	14	6
Circuit D	18	14
Total	116	80

Source (MoE 2020)

The demographic characteristics of the respondents are summarised in Tables 3 and 4.

Table 5: Demographics Characteristics of Pre-service Teachers (N=344)

Gender	Frequency	Percentage (%)
Male	55	16.0 %
Female	289	84.0 %
Age		
18	3	0.9%
19-24	323	93.9%
Above 24	18	5.2%

Source: Field Survey, 2024

Table 6: Demographic Characteristics of In-service Teachers (N=78)

Gender	Frequency	Percentage (%)
Male	7	9.0 %
Female	71	91.0 %
Age		
Above 24	78	100%

Source: Field Survey, 2024.

3.2.1 Selection of Participants for Qualitative Research

Twenty mathematics teachers from the sample used for RQ3 were selected from schools across two regions, representing all eight circuits in the Ghana Education Service (GES) categories (A, B, C, and D) participated in the study. Categories A and D represented schools in urban areas, while Categories B and C represented schools in rural areas (MoE, 2019). The population for this study consists of all final-year pre-service teachers enrolled in early-grade programmes at ten selected Colleges of Education in Ghana, as well as early-grade teachers in the initial years of their teaching careers who are actively employed in four chosen municipal districts across two regions of Ghana. Final-year pre-service teachers were specifically selected because they had completed all the necessary mathematics content courses (MoE 2019). There are seven Colleges of Education in the Central and Western regions of Ghana. Moreover, there are twenty-two districts in the Central region and seventeen districts in the Western region. This location was selected for its convenience. A stratified random sampling technique was used to categorise the schools according to the Ghana Education Service (GES) classification. Schools from each of these categories were then randomly selected for the study. In total, twenty mathematics teachers from forty schools across two regions, representing all eight circuits in the Ghana Education Service (GES) categories (A, B, C, and D), participated in the study. Categories A and D represented schools in urban areas, while Categories B and C represented schools in rural areas (MoE, 2019).

Questionnaires were distributed to all twenty pre-service early-grade teachers and twenty early-grade teachers in the early years of their teaching careers across the eight districts within the Cape Coast Metropolis of the Central Region and the Sekondi-Takoradi Metropolis of Ghana, followed by interviews. During these visits, the study's purpose, the questionnaires' objectives, and completion instructions were discussed with both the pre-service teachers and teachers in the early years of their careers. In every CoE and school visit, the pre-service early-grade teachers and teachers in the early years of their teaching careers demonstrated a willingness to partake in the research following the thorough explanation of the participant information and the assurance of confidentiality regarding their responses. Despite the advantages of questionnaires, such as anonymity, time efficiency, and standardised questions, they also come with limitations as noted by Munn and Drever (1990). In

this study, although participants were willing to participate, ensuring a high response rate for completed questionnaires was a significant concern. Given the teachers who agreed to participate, it was essential to develop strategies to increase response rates and enhance confidence in the results. The questionnaires were administered during the instructional hours of the pre-service teachers. An hour was requested of their time. They were collected on the same day they were administered, and the interviews followed shortly. The teachers, in their early years of teaching, responded after school hours.

3.3 Data Collection Procedure

In collecting data for the study, a letter of introduction and permission was first acquired from Charles University, the Mathematics and Mathematics Education Department. The introductory letter was submitted to seek permission from the Principals of the Colleges of Education (CoE) and the Headteachers of the early-grade schools in the selected municipality to administer the instrument during school hours. Approval was sought from the participants who would partake in the study. Given that the study encompasses both quantitative and qualitative phases, the data collection procedures employed in each phase will be further explained.

Between January and May 2024, two sets of questionnaires (see appendices) were distributed to all 344 pre-service early-grade teachers and the 78 in-service early-grade teachers in the early years of their teaching careers across the eight districts within the Cape Coast Metropolis of the Central Region and the Sekondi-Takoradi Metropolis of Ghana.

Before distributing the surveys, consent was obtained from the CoE and the education Principals to conduct the research in the selected schools. Subsequently, the sampled CoE and schools were visited for a formal introduction to the teachers, and their official consent was obtained, even though they had already agreed to participate in the study during prior telephone conversations.

During these visits, the purpose of the study, along with the aim of the questionnaires and instructions for their completion, was discussed with both the pre-service teachers and teachers in their early years of teaching careers. In every CoE and school visit, the pre-service early-grade teachers and teachers in the early years of their teaching careers demonstrated a willingness to partake in the research following the thorough

explanation of the participant information and the assurance of confidentiality regarding their responses. Despite the advantages of questionnaires, such as anonymity, time efficiency, and standardised questions, they also come with limitations, as Munn and Drever (1990) noted. In the current study, while participants were willing to participate, ensuring a high return rate for completed questionnaires was a significant concern. Given the number of teachers who agreed to participate, it was crucial to devise strategies to boost response rates and enhance confidence in the findings. The questionnaires were administered during the instructional hours of the pre-service teachers, thirty minutes were asked of their time, and they were collected on the same day they were administered. The teachers in their early years of teaching answered theirs after school hours.

3.4 Curricula Analysis

Content or document analysis was employed to answer research questions 1 and 2. Content or document analysis, as defined by Wallen and Fraenkel (2001), examines the contents of documents, whether textual or visual. It contributes meaningful knowledge to the subject of study and generates information beneficial for assessing and improving social or educational activities (Graneheim et al., 2017). This technique objectively extracts the needed information from a document.

In this study, the analysis focused on key aspects of early-grade mathematics education, such as the alignment of curriculum objectives with Pedagogical Content Knowledge (PCK) and Subject Matter Knowledge (SMK), the emphasis on instructional strategies for conceptual understanding and procedural fluency, and the integration of global benchmarks in local educational practices. A systematic approach was employed to examine the structure, content, and pedagogical frameworks embedded in the reviewed materials, allowing for the identification of recurring themes, strengths, and gaps in addressing the needs of early-grade mathematics education.

3.4.1 List of Documents Studied

The list of documents used in this study for analysing research questions 1 and 2 are:

1. Colleges of Education Early-grade B.Ed. Curriculum, this document outlines the curriculum framework, objectives, course descriptions, and pedagogical approaches employed in training early-grade teachers in Ghana.
2. National Kindergarten Mathematics Curriculum developed by NaCCA, this document details the curriculum objectives, contents, and instructional strategies for kindergarten mathematics education in Ghana.
3. The Global Proficiency Framework (GPF) for Mathematics is a globally recognised framework that provides nations and international assessment organisations with a common scale for reporting progress on Indicator 4.1.1 of the Sustainable Development Goals (SDGs). Developed by the UNESCO Institute for Statistics (UNESCO 2021), the GPF defines the minimum knowledge and skills that students must demonstrate at critical points in their learning trajectory. Its significance lies in its ability to standardise benchmarks and ensure that education systems are aligned with international expectations for student proficiency.

3.5 Quantitative Data

To answer research questions 3 and 4, quantitative methods were used, namely the ATMI and MTEB questionnaires; these instruments are standardised, which I will present in the following text.

3.5.1 ATMI

In answering Research Question 3, the Attitudes Towards Mathematics Inventory (ATMI), created by Tapia and Marsh in 2004, was used to measure the attitudes of both pre-service and early-career teachers toward mathematics. The ATMI originally consisted of 40 items on a 5-point Likert scale, ranging from "strongly disagree" to "strongly agree." The questionnaire encompassed six sub-dimensions: confidence, anxiety, value, enjoyment, motivation, and parent/teacher expectations.

The modification of the Likert scale from a 5-point to a 4-point scale has been a subject of considerable discussion in recent literature. In the presented research, the Likert scale was modified to a 4-point version by eliminating the neutral midpoint. This modification aimed to enhance the accuracy of results for several reasons:

respondents might use the neutral midpoint for purposes other than expressing a balanced stance, such as lacking an opinion, hesitating to reveal their viewpoint, not understanding the question, or encountering irrelevant questions (Kulas, & Stachowski 2009). It can be challenging to linguistically convey the concept of neutrality within the continuum of response choices (González-Romá & Espejo, 2003). Again, including a neutral midpoint category often provides limited informative value (Andrich, 1978). Removing the neutral option encourages respondents to make definitive choices, thereby reducing response bias and enhancing the discriminative power of the instrument (Tourangeau et al., 2000). This approach is supported by studies such as those by Krosnick et al., (2018) and Asún et al., (2016), who argue that prompting respondents to choose between distinct options often leads to more reliable data. Subsequent studies have examined the psychometric properties of the ATMI to ensure its reliability and validity across different populations and settings. For instance, García et al., (2021) conducted a confirmatory factor analysis (CFA) with a diverse sample of pre-service teachers and confirmed the six-factor structure of the ATMI, demonstrating strong construct validity. Additionally, García et al., (2021) assessed the internal consistency of the ATMI, reporting Cronbach's alpha coefficients above 0.85 for all sub-dimensions, indicating high reliability. These findings are consistent with those of Tapia and Marsh (2004), who reported strong internal consistency for the original scale, confirming its robustness in various educational settings.

The Attitudes Toward Mathematics Inventory (ATMI) has been applied in various educational contexts to explore attitudes toward mathematics among different teacher groups. For example, Moenikia & Zahed-Babelan (2010) used the ATMI to compare attitudes between mathematics and non-mathematics majors in teacher education programs, finding significant differences in confidence and anxiety levels their study showed that professional development programs positively influenced confidence and enjoyment over time. Furthermore, Jančařík et al. (2023) used the ATMI to examine the attitudes of future teachers of STEM subjects, identifying variations in confidence and perceptions of mathematics as a discipline across different cultural contexts. Their study emphasised the importance of addressing negative attitudes during teacher preparation to foster stronger engagement with mathematics education. Similarly, in a study conducted by (Butakor, 2016; McCallon and Brown 1971) teacher attitudes

toward mathematics were shown to be strongly correlated with their students' attitudes and performance in the subject. This further underscores the critical role that teacher attitudes play in shaping student learning outcomes. Despite these extensive applications of the ATMI, there is a noticeable gap in research on attitudes toward mathematics among early-grade teachers in Ghana. Existing studies predominantly focus on broader teacher education contexts or STEM subjects, leaving the attitudes and beliefs of early-grade educators in Ghana underexplored. This highlights the need for studies targeting this critical group to understand better and address their specific challenges and support needs.

To ensure its applicability in diverse cultural settings, the ATMI has undergone several cross-cultural adaptations. (Lin & Huang, 2014) adapted the ATMI for use with Chinese pre-service teachers, incorporating cultural nuances and validating the instrument within the Chinese educational framework. Their study confirmed the instrument's reliability and validity, suggesting its suitability for non-Western contexts. Additionally, Majeed et al. (2013) focused on validating the Attitudes Toward Mathematics Inventory (ATMI), an instrument designed to assess students' attitudes toward mathematics. Using confirmatory factor analysis (CFA) on data from pre-service teachers in South Australia, the study supported a four-factor model for the ATMI, which includes self-confidence, value, enjoyment, and motivation. The results revealed that while students held a positive view of mathematics' value, their levels of enjoyment, confidence, and motivation were relatively low. This suggests that, although students recognise the importance of mathematics, they do not feel sufficiently motivated or confident to engage deeply with it. The study also confirmed the reliability and validity of the ATMI, highlighting its usefulness as a tool for measuring students' attitudes toward mathematics across different cultural contexts. The Attitudes Towards Mathematics Inventory (ATMI) remains a widely used instrument for assessing teachers' attitudes toward mathematics. Through its comprehensive sub-dimensions and thoughtful modifications, such as the transition from a 5-point to a 4-point Likert scale, the ATMI effectively captures nuanced attitudes while minimising response biases. Recent validations, cross-cultural adaptations, and integrations with digital platforms underscore its versatility and enduring relevance in educational research. Continued enhancements and methodological refinements ensure that the ATMI remains a pivotal tool in

understanding and improving mathematics education through the lens of teacher attitudes.

3.5.2 MTEBI

In answering Research Question 4, the Mathematics Teaching Efficacy beliefs Instrument (MTEBI) was employed to assess the self-efficacy beliefs and outcome expectancy of pre-service and early career teachers in mathematics education. The MTEBI is a modified version of the Science Teaching Efficacy beliefs Instrument (STEBI-B) by Enochs and Riggs (1990), originally designed to assess teachers' beliefs regarding their ability to teach science effectively. Over time, the MTEBI has been adapted and refined to measure mathematics teaching self-efficacy and teaching outcome expectancy specifically. This instrument has been widely used in educational research, with studies by Giles et al. (2016), Moody and DuCloux (2015), Newton et al. (2012), Segarra and Julià (2020), and Swars et al. (2009) demonstrating its reliability and validity in various contexts.

The original MTEBI consisted of 21 items on a five-point Likert scale, where respondents indicated their level of agreement with each statement, ranging from one (strongly disagree) to five (strongly agree). In line with the approach of Liu et al. (2007) and Segarra and Julià (2020), the third Likert scale option, "uncertain," was removed in this study to encourage participants to take a definitive stance on their beliefs. This modification was intended to increase clarity and ensure more meaningful data collection, as participants were prompted to clearly indicate their confidence in their teaching practices.

The MTEBI measures two primary constructs: Mathematics Teaching Self-Efficacy (MTSE) and Mathematics Teaching Outcome Expectancy (MTOE). MTSE refers to a teacher's beliefs in their ability to effectively teach mathematics, manage classroom dynamics, and engage students in mathematical reasoning. Teachers with high MTSE are more likely to implement innovative teaching strategies, foster student engagement, and create an inclusive learning environment. MTOE, on the other hand, concerns the teacher's expectations regarding the positive outcomes of their teaching, such as improvements in student achievement, motivation, and interest in mathematics. Teachers with high MTOE believe that their teaching efforts will lead to tangible improvements in student learning outcomes, and they are more likely to persist in their instructional efforts despite challenges.

Extensive research has validated the MTEBI's reliability and validity across diverse educational contexts. Studies have confirmed its ability to measure both MTSE and MTOE effectively. For example, Giles et al. (2016) reported that the MTEBI demonstrated high internal consistency, with Cronbach's alpha values exceeding 0.90 for both constructs, indicating robust reliability. In addition, factor analysis studies, such as those conducted by Segarra and Julià (2020), have provided evidence of the MTEBI's factorial validity. These studies confirmed the two-factor structure of the instrument across different populations, demonstrating its adaptability and robustness as a tool for assessing mathematics teaching efficacy.

Recent studies have expanded the use of the MTEBI, adapting it to various cultural and educational settings. Cakiroglu (2008) adapted the instrument for USA and Turkey pre-service teachers, offering valuable insights into how cultural nuances can influence teaching efficacy beliefs in non-Western contexts. Their findings suggest that while the core dimensions of MTSE and MTOE remain consistent, cultural factors such as attitudes towards authority and traditional teaching methods can affect how efficacy beliefs are shaped. This adaptation highlights the MTEBI's versatility and applicability beyond Western educational systems.

Similarly, Swars et al., (2009) employed the MTEBI in a longitudinal study that tracked pre-service teachers' efficacy beliefs from their initial teacher training through their first years of teaching. Their study provided insights into how MTSE and MTOE evolve over time and the factors that contribute to the stability or change in these beliefs. Their research demonstrated that while pre-service teachers' beliefs may fluctuate during their training, sustained exposure to positive teaching experiences and professional development can help stabilize and strengthen these beliefs, contributing to improved teaching practices and student outcomes.

Huinker & Madison (1997) used the MTEBI to assess the impact of targeted professional development programs on pre-service teachers' mathematics teaching efficacy. Their study found significant improvements in MTSE scores post-intervention, suggesting that well-designed professional development programs can effectively enhance teachers' beliefs in their teaching abilities and their expectations of student outcomes. This finding underscores the importance of providing pre-service teachers with continuous opportunities for growth and reflection throughout their training, particularly in mathematics education.

The MTEBI continues to be an invaluable tool for teacher education programs, helping to inform curriculum development and instructional strategies aimed at enhancing pre-service teachers' confidence in mathematics teaching. By accurately assessing MTSE and MTOE, educators can identify areas where teachers may need additional support and tailor professional development initiatives accordingly. Gresham (2008) emphasise that measuring teachers' self-efficacy beliefs is critical to fostering effective teaching practices and improving student outcomes in mathematics education. Through continuous validation and adaptation, the MTEBI remains relevant and effective in diverse educational landscapes, playing a crucial role in improving mathematics teaching and learning.

3.6 Mixed method

A mixed-method approach was used to investigate the fifth research question guiding this study: What level of Pedagogical Content Knowledge for teaching mathematics do early career teachers and pre-service early-grade teachers possess? The hypothesis accompanying this research question was: There is no significant difference in the Pedagogical Content Knowledge between early career teachers and pre-service early-grade teachers. A mixed-method research (MMR) approach was employed in this study to investigate the level of Pedagogical Content Knowledge (PCK) possessed by early career teachers and pre-service early-grade teachers. The accompanying hypothesis for this research question was: There is no significant difference in the PCK between early career teachers and pre-service early-grade teachers.

Mixed-method research (MMR) combines qualitative and quantitative methodologies within a single study to provide a more comprehensive understanding of the research problem (Creswell & Plano Clark, 2007). By integrating both data types, MMR allows for the triangulation of findings, meaning that the strengths of one method can help to counterbalance the weaknesses of the other. This integration allows researchers to address different aspects of a research question that may be better suited to quantitative or qualitative methods (Creswell, 2009). As Creswell and Plano Clark (2007) note, MMR is a design that blends philosophical assumptions, data collection methods, and analysis techniques from both paradigms to provide a more complete perspective on the research question. The approach ensures that the researcher has access to both the breadth of quantitative data and the depth of qualitative insights, facilitating a comprehensive investigation of the research problem.

This study collected quantitative data through standardised surveys and assessments to measure the level of PCK among the teachers. These quantitative measures objectively evaluated teachers' subject matter knowledge, teaching strategies, and understanding of how to adapt their pedagogy to meet students' needs. The use of structured surveys and assessments is consistent with the work of Martin & Jamieson-Proctor (2019), who emphasise that standardised measures can provide reliable data on teacher knowledge and instructional practices. The quantitative data also offered insights into the differences in PCK levels between early-career teachers and pre-service teachers, contributing to the evaluation of the study's hypothesis.

Qualitative data were gathered through semi-structured interviews, which provided a deeper understanding of how teachers' PCK influences their teaching practices. The qualitative approach helped capture the teachers' experiences, offering rich, descriptive data that highlighted the nuances of how PCK is applied in real-world teaching situations (Merriam, 2009). These data collection methods align with those used by Shulman (1986), who argued that PCK is understood through examining teachers' reflections and instructional practices.

By combining these quantitative and qualitative data sources, this mixed-methods approach enabled a fuller exploration of the research question and hypothesis. The quantitative results provided a broad understanding of PCK levels across different groups of teachers, while the qualitative data enriched the interpretation of these findings by offering context and deeper insights into how PCK is enacted in the classroom. Integrating these two methods ensures that the findings are not only statistically significant but also contextually meaningful, providing a comprehensive understanding of the factors that contribute to teachers' PCK in early-grade mathematics education. Fetters et al. (2013) noted that mixed-method research offers the unique advantage of integrating different data types to answer complex research questions more effectively than qualitative or quantitative methods alone.

3.6.1 Quantitative Phase

The primary research question that directed this study was, What level of pedagogical content knowledge for teaching mathematics do early career teachers and pre-service early-grade teachers possess. To address the research inquiry, data were gathered from achievement tests that measured the pedagogical content knowledge (PCK) of

mathematics teachers. The test scores for each group of grade teachers were analysed. The items included in the Mathematics Pedagogical Content Knowledge Instrument (MPCKI) were created for a study by Martin in 2017. These selected items were closely aligned with the mathematics content being studied by the participants, all fourth-year pre-service teachers, and corresponded to the questions in the National Standardized Test for Basic Four (4) in Ghana. The aim was to equip pre-service teachers with the essential knowledge and skills required to teach critical areas of the mathematics curriculum, such as algebra, measurement, geometry, and probability and statistics at the primary school level (Hagan et al., 2020; Martin, 2017).

3.6.2 Qualitative Phase

Preparation of a Semi-Structured Interview Guide

The semi-structured interview guide was designed to capture comprehensive insights into pre-service and in-service teachers' experiences with Pedagogical Content Knowledge (PCK). The guide was structured around six core themes, each addressing key components of mathematics teaching. These themes were carefully selected to explore how teachers' knowledge and skills evolve, the factors influencing PCK, the challenges faced, and the role of professional development in shaping teaching efficacy.

The questions were crafted to prompt open-ended responses, allowing participants to reflect on their experiences and provide rich, detailed answers. In particular, the guide included both general and specific questions to cover broad aspects of PCK while also allowing space for teachers to discuss individual challenges and successes. The flexibility of the semi-structured format enabled the interviewer to probe deeper into specific topics as needed, ensuring that a wide range of experiences and perspectives were captured.

The audio recording of the interviews was a fundamental part of the data collection process, providing a reliable and accurate record of participants' responses. The recordings allowed the interviewer to maintain focus on the conversation and engage with the participants without being distracted by manual note-taking. This also allowed for a more natural flow of conversation, as participants were free to elaborate

on their answers without the pressure of having to remember every detail for later recollection.

Using audio recordings ensured that the participants' words were captured verbatim, preserving the nuances of their responses. This was particularly important for this research, where subtle variations in tone, emphasis, and phrasing can provide valuable context for understanding teachers' perspectives. The recordings were stored securely, following ethical guidelines to maintain confidentiality and protect participants' privacy.

Once the interviews were transcribed, I reviewed the transcripts alongside the audio recordings to ensure accuracy and to capture any non-verbal cues that might inform the analysis, such as pauses, tone, or changes in speech patterns. This comprehensive approach to data collection provided a rich, detailed foundation for analysing the complex relationships between teachers' attitudes, PCK, and teaching efficacy beliefs.

The combination of a well-structured interview guide and audio recording facilitated an efficient, thorough, and accurate data collection process that supported a detailed exploration of teachers' pedagogical content knowledge and the factors that shape it

The interviews were audio-recorded with the participants' consent to ensure accuracy and completeness. The recordings were transcribed verbatim to capture the nuances of participants' responses, including tone and emphasis, which added depth to the analysis. Transcriptions were reviewed for accuracy before coding and thematic analysis.

During the analysis phase, Atlas.ti 22 software was used to support data organisation and coding. The software facilitated the systematic categorisation of themes and sub-themes, enabling the identification of patterns, relationships, and outliers in the data.

The themes were further explored by examining participants' illustrative examples and reflections, which enriched the analysis and provided insights into their PCK.

CHAPTER FOUR – RESULTS, FINDINGS AND ANALYSIS OF DATA

Introduction

This chapter presents the findings stemming from the analysis of data presented in the previous chapter.

Content or document analysis was conducted to examine curriculum objectives and pedagogical approaches within the context of early-grade mathematics education. Descriptive statistics were used to outline the fundamental characteristics of the quantitative data collected from the questionnaires, while qualitative data from interviews were analysed to gain deeper insights. These analyses illustrate pre-service and in-service teachers' attitudes, efficacy, beliefs and knowledge toward mathematics.

Each research question will be presented separately. Important findings will be summarised and discussed.

4.1 Research Question 1

This section presents the results and findings of the data collected through content or document analysis to address research question 1 (RQ1):

What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education (CoE) in Ghana and the National Kindergarten (KG) Mathematics Curriculum?

The findings of research question have been accepted for publication in (Amusuglo, Jančařík, 2024a).

The findings are categorised into objectives, course descriptions, content comparisons, and pedagogical approaches, followed by a discussion of their implications and conclusion.

4.1.1 Results

Objectives of the CoE Early-grade Curriculum and the national KG curriculum

In relation to the objectives, the CoE B.Ed. Early-grade Curriculum had no specific objectives for mathematics; the objective was general for all subjects. The National KG curriculum had a specific objective for mathematics. In common for both curricula is the emphasis on the use of ICT, creativity and critical thinking skills.

Course description and Learning outcomes of the two curricula

Another area of comparison is subjects/course description and learning outcomes. Here, a comparison was done to find out whether detailed descriptions were given to the courses/subjects to be studied. Concerning course description, the national KG curriculum contained no description of topics relating to mathematics. This makes it difficult to ascertain the specific content of mathematics that is required to be taught. For example, in the national KG curriculum, the topic for sub-strand 2 for KG I, Term 1, where mathematics is first introduced, is ‘The Parts of the Human Body and their Functions’. Under this sub-strand, teachers are expected to teach the four subjects in the curriculum (Language and Literacy; Numeracy [mathematics]; Creative Arts; and Our World and Our People) using the human parts as an exemplar. A description was not provided about the topics or areas of the subjects that are to be taught. Instructions were only given about the pedagogical approach. In the case of mathematics, the following instruction was stated:

Count the number of the names of the body parts in songs by clapping to the rhythm. Learners sing three different songs, clap to the rhythm and count the number of parts they hear in the songs. E.g., My head, my shoulder, my knee (3 names). Help them understand that the last number names are the number of objects or items counted (MoE, 2019, p. 4)

Although the above suggests that teachers are to teach counting numbers using parts of the body as exemplars, the topic (Numbers) is also not explicitly stated explicitly in the curriculum. The CoEs B.Ed. Early-grade Curriculum is different as it includes descriptions for all the courses in mathematics content. Numbers and Algebra, for instance, have the following as course descriptions and learning outcomes clearly stated in the curriculum; specifically, for numeracy (Mathematics), there is the need to

do auditing of subject knowledge to establish and address student teachers' learning needs, perceptions and misconceptions in Numbers and Knowledge, skills and understanding of the fundamental concepts of Numbers and Algebra, as well as the ability to identify one's characteristics (culture, ethnicity, religion, family constellation, socio-economic background, disability), can lead to a student teacher's ability to apply these two areas of mathematics in patterning, generalization and algebraic reasoning in reminding the student teachers of the role of deductive reasoning in developing mathematical ideas. Topics in Number and Algebra include recognizing and developing patterns, using numbers and number operations, properties of numbers, the concept of sets, number bases and modulo arithmetic, and algebraic expressions. In addition, student teachers will explore operations on algebraic expressions and apply mathematical properties to algebraic equations and functions. Using many examples of different local and global contexts, student teachers will solve mathematical problems using equations, graphs and tables to investigate linear and quadratic relationships (MoE, 2019, p. 17)

From the above, a description is given of the course and the various topics within numbers and algebra that need to be taught in the CoEs (B.Ed. Early Grade) curriculum. However, this is not explicit in the national KG curriculum, which makes it difficult to understand the mathematics content that the teacher is required to teach the KG learners.

4.1.2 Discussion

The content of both curricula is related. Both curricula had a similar scope of content, including numbers, algebra, geometry, measurement and handling data. The pedagogical approaches such as problem-solving approaches, scaffolding, creativity, and play-based activities were inculcated into teaching mathematics. According to Suurtamm et al. (2015), the problem-solving approach provides students with multiple opportunities to link mathematical concepts and build conceptual understanding. Similarly, Bruns et al. (2017) explored methods to encourage students to think mathematically and suggested that it is important to present complex and rich problems in the mathematics classroom. These problems should offer, various approaches, opportunities for scaffolding, and foster engagement without requiring rigid procedural steps.

This problem-solving approach is well integrated into the KG and B.Ed curricula, which will help learners use mathematical concepts to solve real-world problems.

Scaffolding was also another pedagogical approach that was found in both curricula. Researchers have described instructional scaffolding as the cornerstone to assisting struggling learners in accessing the core curriculum (Coyne et al., 2011). To determine the amount of instructional scaffolding to provide during an instructional task, Clarke et al. (2015) recommended that teachers consider whether learners have the background knowledge required to accomplish the task. They further stated that in situations where learners are less prepared or the task is complex or novel, teachers would have to provide greater support to engage learners in key mathematics content deeply (Clarke et al., 2015). This is important because both the KG and B.Ed curricula emphasise the inclusion of learners with mathematics learning disabilities. The inclusion of a scaffolding approach to instructional delivery will enable teachers to meet the learning needs of all learners. The play-based instructional approach took the centre of the two curricula. Although the CoE B.Ed early-grade curriculum did not give a detailed description of how play-based instruction should be delivered, it did state it as part of the teaching approach for all mathematics to be studied by initial teacher education students. The KG curricula, on the other hand, provided many details of how the play activities should be done. Play can be defined as activities that ‘are fun, voluntary, flexible, involve active engagement, have no extrinsic goals, involve active engagement of the child, and often have an element of make-believe’ (Weisberg et al., 2013). Gasteiger (2015) recounts that early learning needs should be based on play. He added that innovative approaches to early mathematics should not only be developmentally adequate and effective but also compatible with kindergarten pedagogy, which is play-based (Gasteiger, 2015).

4.1.3 Conclusion

As kindergarten learners are highly motivated to learn, but not in a formal, instructional way, play can be regarded as a powerful vehicle for learning (Cankaya et al., 2023; Hauser, 2005). Since both curricula are restructured, it is recommended that the KG mathematics curriculum be integrated into the CoE early-grade mathematics curriculum so that pre-service teachers will have an idea of exactly what they will experience in practice.

4.2 Research Question 2

RQ2 How do Ghana’s national kindergarten and Colleges of Education early-grade mathematics curricula align with the knowledge and skills outlined by the Global Proficiency Framework (GPF)?¹

The result of Research Question 2 has been published in Amusuglo & Jančařík (2024). In this section, I present the analysis results, followed by a discussion of the findings and conclusion.

4.2.1 Results

Table 7: Structure of the Global Proficiency Framework

Domain	Construct	Sub-construct	Grade 1	Grade 2	Grade 3
Number and operations	Whole numbers	Identify and count in whole numbers, and identify their relative magnitude	✓	✓	✓
		Represent whole numbers in equivalent ways	✓	✓	✓
		Solve operations using whole numbers	✓	✓	✓
		Solve real-world problems involving whole numbers	✓	✓	✓
	Fractions	Identify and represent fractions using objects, pictures, and symbols, and identify relative magnitude			✓
	Algebra	Relations and functions	Demonstrate an understanding of equivalence		✓
Patterns		Recognize, describe, extend, and generate patterns	✓	✓	✓
Measurement	Length, weight, capacity, volume, area, and perimeter	Use non-standard and standard units to measure, compare, and order	✓	✓	✓
		Tell time	✓	✓	✓
		Solve problems involving time		✓	✓

¹ The findings of RQ 2 has been published, Amusuglo, M., & Jančařík, A. (2024b). Global proficiency framework: Analysis of national and Colleges of Education Curricula in Ghana. South African Journal of Childhood Education, 14(1), 1-9

	Currency	Use different currency units to create amounts	✓	✓	✓
Geometry	Properties of shapes and figures	Recognise and describe shapes and figures	✓	✓	✓
	Spatial visualisation	Compose and decompose shapes and figures	✓	✓	✓
	Position and direction	Describe the position and direction of objects in space	✓	✓	✓
Statistics and probability	Data management	Retrieve and interpret data presented in displays	✓	✓	✓

Source: UNESCO (2021).

Table 7 shows the domains, construct, and sub-constructs of the Grades 1–3 GPF for mathematics and the national early grade curriculum for Ghana. The sub-constructs and sub-strands represent the knowledge and skills expected to be attained by learners in Grades 1–3 for mathematics proficiency.

To what extent are the domains of the Ghanaian national early grade mathematics curriculum aligned to the Global Proficiency Framework for mathematics?

The GPF has five domains for mathematics at the early grade level. These include numbers and operations, algebra, measurement, geometry, statistics, and probability. Each domain has a construct and sub constructs. Almost all of the constructs under the five domains have Global Proficiency Descriptors (GPDs) for all grade levels, except the construct of fractions under numbers and operations, which has GPDs only for Grade 3. This means that according to the GPF, the sub construct of fractions (such as identifying and representing fractions using objects, pictures, and symbols) should be taught in Grade 3. Again, under the domain of algebra, the construct, relations, and functions have no GPD for Grade 1, which suggests that GPF sub-constructs like demonstrating an understanding of equivalence are not included for Grade 1.

The Ghanaian curriculum has four main domains, also called strands, with sub-strands corresponding with the constructs and sub constructs in the GPF. Generally, the strands in the Ghanaian national early grade mathematics curriculum align with the

domains of the GPF. While geometry and measurement are merged as a single strand in the early-grade national mathematics curriculum, its content aligns with the geometry and measurement domains in the GPF. Another apparent difference is the use of data in the fourth strand of the early grade national mathematics curriculum, which focuses on statistics and probability, whereas the GPF lists it as a separate domain. Despite the different terminologies, both the national curriculum and the GPF focus on organising, representing, and interpreting data. This observed consistency makes the Ghanaian early-grade mathematics national curriculum a reflection of the GPF.

In what ways do the domains of the Bachelor of Education curriculum for pre-service early-grade teachers in the Colleges of Education in Ghana align with the Global Proficiency Framework for Mathematics?

Table 8: National Early-Grade Mathematics Curriculum

STRANDS	SUB-STRANDS	Grade 1	Grade 2	Grade 3
Number	Whole Numbers: Counting, Representation and Cardinality)	√	√	√
	Whole Numbers Operations	√	√	√
	Fractions, Representation and Relationship	√	√	√
Algebra	Patterns and Relationships	√	√	√
Geometry and Measurement	Lines and Shapes	√	√	√
	Position and Transformation	√	√	√
	Measurements	√	√	√
Data	Data (Collection, Presentation, Analysis and Interpretation	√	√	√
Source: MoE (2019)				

Table 8 shows the mathematics contents of the Bachelor of Education (B.Ed.) curriculum for pre-service early-grade teachers in Colleges of Education. The course

contents include numbers and algebra, geometry, handling data, theories of learning numeracy in the early grades, and teaching and assessing numeracy for early-grade students.

Analysis of the B.Ed. Early grade curriculum and its alignment with the GPF revealed that both contents are consistent. Similar mathematical domains, including numbers, algebra, geometry, measurement, and handling data, run throughout both curricula. The only difference observed was the emphasis on early grade numeracy development theories in the B.Ed. Curriculum, which is absent in the GPF. However, this is understandable, as early-grade learners in Grades 1–3 do not require learning theories in mathematics at that foundational stage. On the other hand, pre-service teachers in Colleges of Education need to learn the theoretical foundations for teaching mathematical concepts effectively.

Here are some learning indicators and exemplars in the national early-grade mathematics curriculum and B.Ed. Curriculum related to the Global Proficiency Framework.

Table 9: Mathematics contents of B.Ed Curriculum for pre-service early grade teachers in Colleges of Education.

Course Content	Topics
Numbers and Algebra	<p>Numbers and Numeration Systems: Learning, teaching and applying Operations and Properties on Integers. (fractions, decimals, percentages)</p> <p>Concept of Sets (Sets of numbers, Venn diagrams) and word Algebraic expressions, equations and inequalities</p> <p>Every day and commercial arithmetic (Ratio, rates, proportion, scales, percentages (taxation, discount, commissions)</p> <p>Number bases and Modular arithmetic</p>
Geometry and Handling Data	<p>Plane Geometry Patterns in Shape</p> <p>Geometrical Constructions</p> <p>Vectors and Bearing:</p>

	Basic trigonometry:
	Global Mathematics
	Mensuration
	Introductory Statistics (Patterns in data):
	Basic probability
Theories in the Learning of Numeracy in the Early Grade	<p>Why do we teach mathematics in school?</p> <p>Teacher beliefs about mathematics and their relation to teaching beliefs underlying the current Early Grade official curriculum and inclusive classroom practices</p> <p>Major theories of learning and teaching of Early Grade mathematics in inclusive classrooms</p> <p>Multiple intelligence and early-grade mathematics</p> <p>Factors that affect teaching and learning mathematics in the Early Grade</p>
Teaching and Assessing Numeracy II for Early Grade	<p>The mathematics curriculum</p> <p>Counting and Number relationships</p> <p>Place value 10 to 1,000</p> <p>Addition: numbers within 19; and then numbers within 99</p> <p>Classroom assessment in mathematics in the Early Grade</p> <p>Subtraction: numbers within 19; and then numbers within 99</p> <p>Shape, space and Measurement</p> <p>Source (MoE 2019)</p>

The GPF has four minimum proficiency levels: Below, Partially Meets Global Minimum Proficiency, Meets Global Minimum Proficiency, and Exceeds Global Minimum Proficiency. Table 3 shows the level of descriptors in the GPF for the domains of number and operations and fractions in both the national early grade mathematics curriculum and the B.Ed. curriculum. The majority of the indicators in

the national mathematics curriculum exceed the minimum global proficiency level. For instance, the Grade 1 indicator for number and operations in the national curriculum, which involves counting given numbers between 0 and 100, exceeds the minimum proficiency level set by the GPF. Additionally, the concept of fractions is included in the national curriculum for Grades 1–3, whereas the GPF does not include fractions in Grades 1 and 2.

4.2.3 Discussion

The results of this study show an alignment between the domains in the GPF and the National Curriculum for Grades 1 to 3. For example, the domain name "Number and Operations" has the construct "Whole Numbers" with sub constructs such as "Identify and count whole numbers, and identify the relative magnitude of the whole number." This aligns with the GPF sub constructs for Grades 1–3, which include "Count, read, and write whole numbers" and "Compare and order whole numbers." From the GPF perspective, early graders are expected to gain knowledge and skills in writing whole numbers and comparing and ordering them by the end of Grade 3. This is mirrored in the national curriculum for Grades 1–3, where in the strand "Number," the sub-strand "Whole Numbers," learners are expected to acquire knowledge and skills in naming numbers, counting, representing, and comparing numbers, as well as using place value and the number line, and comparing quantities and numbers up to 100. Thus, the knowledge and skills expected in the GPF for early graders align well with what is presented in the national mathematics curriculum from Grades 1–3 in Ghana.

The findings also show that the GPF and B.Ed. Early-Grade curricula align closely, with only one omission. The B.Ed. early-grade curriculum includes a focus on theories of early-grade numeracy development, which is absent in the GPF. However, this omission is understandable, as early graders in Grades 1–3 do not need to learn theories in mathematics at this foundational stage. On the other hand, pre-service teachers in Colleges of Education need to learn the theoretical foundations of teaching and learning mathematical concepts to better prepare them for teaching the subject at an early grade. This reflects the goal of the B.Ed. curriculum to produce teachers who are well-trained, competent, and knowledgeable in subjects like numbers, algebra, geometry, and data handling.

Schmidt et al., (2005) argued that coherence is an important characteristic that defines high-quality standards. When there are international standards to compare against, it becomes easier to establish cohesive norms. The alignment between the national mathematics curriculum and the GPF indicates that the Ghanaian national mathematics curriculum is up to global standards. The results also suggest that the indicators in the national early-grade mathematics curriculum generally meet or even exceed the Global Minimum Proficiency Levels (Table 3). This is a positive outcome, as it implies that the curriculum is designed to ensure that learners develop a solid foundation in mathematics skills and concepts. The fact that many indicators in the national mathematics curriculum exceed the minimum proficiency levels set by the GPF is a significant finding, suggesting that the national curriculum sets higher expectations for learners in terms of mathematics proficiency compared to global standards. This could lead to better-prepared learners who will be more competent in mathematics.

Another noteworthy finding is the inclusion of fraction concepts in the national early-grade curriculum from Grades 1–3, while fractions are not applicable in Grades 1 and 2 in the GPF. This suggests that the national curriculum places a greater emphasis on teaching fractions at an earlier stage. This could have implications for learners' overall mathematical understanding and preparedness. The results also highlight the focus on pedagogy in the B.Ed. curriculum, specifically on how pre-service teachers can effectively teach mathematics concepts at the early-grade levels. This is important for ensuring that teachers are well-prepared to deliver the curriculum and support students in their mathematical learning.

The alignment of the national early-grade and B.Ed. curricula with the GPF has several advantages. Firstly, it ensures that Ghanaian Early Childhood Education (ECE) is coherent and consistent. By harmonising the curricula, teachers can concentrate on the fundamental knowledge and skills critical for learners' growth in mathematics. Secondly, this alignment facilitates smoother transitions for learners between academic levels. When curricula are interconnected, learners can move through their education more seamlessly without experiencing sudden shifts in material or teaching methods, which confirms the claims of Reddy et al. (2016).

Finally, comparing Ghana's national curriculum with international standards like the GPF makes it easier to identify areas for improvement to bring the educational system

up to standard. Aligning the national curriculum with international standards aids students in gaining a thorough understanding of mathematical concepts (Luneta, 2014).

4.2.4 Conclusion

The findings show that Ghana's early-grade mathematics curriculum and the B.Ed. curriculum for pre-service teachers align with international standards, particularly the GPF. This alignment ensures that learners and teachers are well-prepared for national and global assessments, reflecting a commitment to educational excellence. Moreover, the inclusion of theoretical foundations in the B.Ed. curriculum highlights the critical role of teacher training in bridging the gap between subject matter knowledge and effective teaching practices.

The results align closely with the themes of my thesis, which emphasise the interplay between curriculum standards and teacher knowledge in mathematics education. By exceeding global minimum standards and emphasising pedagogical preparation, this suggests that Ghana will be in a position to enhance mathematical learning outcomes and contribute to global educational development. Future research could explore the direct impact of these curricula on student achievement and the long-term effectiveness of teacher training programmes.

4.3 Research Question 3

RQ 3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana?

The findings of research question 3 have been accepted for publication in Amusuglo et al., (2024).

4.3.1 Results

The aim was to find out pre-service and in-service teachers' attitudes towards mathematics. Respondents were asked to indicate on a 4-point Likert scale the extent to which they agree or disagree with the list of statements pertaining to attitude towards mathematics. The mean score of the responses is compared with 2.5 (thus, $[1+2+3+4]/4 = 2.5$). A mean score above 2.5 indicates that respondents agreed with the statement, whereas scores below 2.5 show that students disagreed with the

statement. Details of pre-service and in-service teachers' attitudes towards mathematics are found in Table 10 and Table 11, respectively.

Table 10: Pre-service Teachers Attitudes Towards Mathematics (N=344)

Statements	Mean	SD
Enjoyment		
I really like mathematics	3.14	.35
I learn mathematics easily	3.15	.36
I have a lot of self-efficacies when it comes to mathematics	3.13	.33
I am comfortable answering questions in mathematics class	3.18	.38
I believe I am good at solving mathematics problems	3.18	.38
I would prefer to do an assignment in mathematics than write an essay	3.17	.38
I am confident that I could learn advanced mathematics	3.14	.35
Mathematics does not scare me at all.	3.17	.37
Mathematics is a very interesting subject.	3.13	.34
I like to solve new problems in mathematics.	3.13	.34
I am able to solve mathematics problems without too much difficulty.	3.16	.36
Means of Means	3.15	.36
Self-confidence		
Mathematics makes me feel uncomfortable.	3.14	.39
My mind goes blank, and I am unable to think clearly when working with mathematics.	2.68	.75
Mathematics is one of my most dreaded subjects.	3.13	.34
It makes me nervous to even think about having to do a mathematics problem	2.45	.81
I am always under a terrible strain in mathematics class	3.14	.35
When I hear the word mathematics, I have a feeling of dislike	3.17	.40
Studying mathematics makes me feel nervous	3.13	.36
I feel a sense of insecurity when attempting mathematics	3.13	.39
Mathematics is dull	3.18	.43
Mean of Means	3.02	.47

Value		
I would like to avoid using mathematics in college.	3.13	.38
I believe studying mathematics helps me with problem-solving in other areas.	3.19	.39
A strong math background could help me in my professional life.	3.21	.41
I think studying advanced mathematics is useful.	3.18	.38
Mean of Means	3.18	.39
Parent/teacher expectations with maths		
Mathematics helps develop the mind and teaches a person to think	3.15	.36
Mathematics is important in everyday life.	3.18	.39
Mean of Means	3.17	.38

Source: Field Survey, 2024

Table 10 shows that pre-service teachers agreed to all the dimensions under attitude towards mathematics, which were value (M= 3.18, SD= .39), parent/teacher expectation with maths (M= 3.17, SD= .38), enjoyment (M= 3.15, SD= .36), and self-confidence (M= 3.02, SD= .47). Generally, pre-service teachers have a positive attitude towards mathematics.

Table 11: In-service Teachers Attitudes Towards Mathematics (N= 78)

Statements	Mean	SD
Enjoyment		
I really like mathematics	3.12	.32
I learn mathematics easily	3.17	.38
I have a lot of self-efficacies when it comes to mathematics	3.12	.32
I am comfortable answering questions in mathematics class	3.19	.40
I believe I am good at solving mathematics problems	3.14	.35
I would prefer to do an assignment in mathematics than write an essay	3.09	.29
I am confident that I could learn advanced mathematics	3.09	.29
Mathematics does not scare me at all.	3.08	.27
Mathematics is a very interesting subject.	3.13	.34
I like to solve new problems in mathematics.	3.12	.32

I am able to solve mathematics problems without too much difficulty.	3.10	.31
Means of Means	3.12	.33
Self-confidence		
Mathematics makes me feel uncomfortable.	3.12	.32
My mind goes blank, and I am unable to think clearly when working with mathematics.	2.38	.71
Mathematics is one of my most dreaded subjects.	3.06	.25
It makes me nervous to even think about having to do a mathematics problem	2.45	.73
I am always under a terrible strain in mathematics class	3.10	.31
When I hear the word mathematics, I have a feeling of dislike	3.15	.36
Studying mathematics makes me feel nervous	3.12	.32
I feel a sense of insecurity when attempting mathematics	3.14	.35
Mathematics is dull	3.14	.35
Mean of Means	2.96	.41
Value		
I would like to avoid using mathematics in college.	3.09	.29
I believe studying mathematics helps me with problem-solving in other areas.	3.14	.35
A strong math background could help me in my professional life.	3.14	.35
I think studying advanced mathematics is useful.	3.13	.34
Mean of Means	3.13	.33
Parent/teacher expectations with maths.		
Mathematics helps develop the mind and teaches a person to think	3.09	.29
Mathematics is important in everyday life.	3.08	.27
Mean of Means	3.09	.28

Source: Field Survey, 2024.

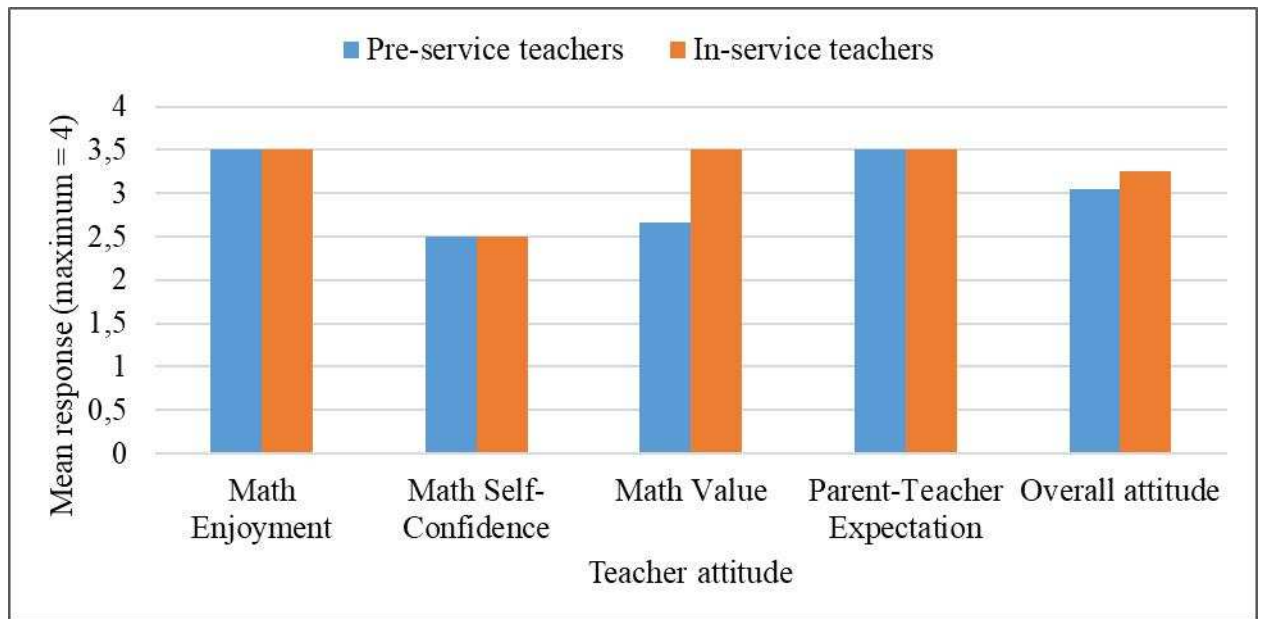


Figure 1: In-service Teachers Attitudes Towards Mathematics (N= 78)

Source: Field Survey, 2024.

4.3.2 Discussion

The analysis of the results presented in Tables 10 and 11 reveals significant insights into the attitudes of pre-service and in-service teachers toward mathematics, highlighting both commonalities and differences in their perceptions. Both groups demonstrated overall positive attitudes, indicating a foundational appreciation for mathematics as an important subject. This positivity is reflected in their agreement with statements across various dimensions, including enjoyment, self-confidence, value, and parent/teacher expectations. The enjoyment dimension of the study showed that pre-service teachers reported a higher level. While this finding suggests that pre-service teachers may have a marginally more positive attitude toward enjoying mathematics. This indicates that both groups generally find mathematics enjoyable, which is a promising sign for future mathematics instruction. Ainley and Ainley's (2011) assertion that enjoyment in mathematics is characterised by positive emotional experiences and satisfaction derived from engaging with mathematical activities resonates strongly with these results.

This finding aligns with other studies that emphasise the importance of enjoyment in mathematics education. For instance, Köller et al., (2001) found that students' enjoyment of mathematics positively correlates with their motivation to engage with

the subject and their overall performance. This indicated that enjoyment is a crucial factor influencing students' attitudes toward mathematics and their willingness to pursue advanced mathematical studies. This suggests that fostering enjoyment in mathematics should be a priority for teacher education programmes.

The slightly higher enjoyment reported by pre-service teachers may stem from their recent experiences in training, where innovative teaching practices and interactive learning environments are often emphasised. This exposure may foster a sense of excitement and curiosity about mathematics that, over time, may diminish for in-service teachers who encounter the practical challenges of teaching. Such challenges may include standardised testing pressures, diverse student needs, and curriculum constraints, which can dampen enthusiasm (Primi et al., 2020). Therefore, it is essential to explore strategies for sustaining this enjoyment of mathematics among in-service teachers. Ongoing professional development that reinforces the joy of teaching the subject, along with collaborative lesson planning, could provide teachers with new ideas and perspectives that rejuvenate their approach to mathematics instruction. The self-confidence dimension revealed a more pronounced gap between the two groups, with pre-service teachers This discrepancy may be attributed to several factors. As Stankov (2013) emphasised, confidence significantly influences students' successful engagement with mathematics learning. Pre-service teachers, being relatively new to the field, may not have faced as many challenges or setbacks as their in-service counterparts, contributing to their higher self-confidence levels.

This finding is consistent with research by Tschannen-Moran and Woolfolk Hoy (2001), who found that teacher self-efficacy is crucial for effective teaching and student learning. Their study highlighted that new teachers often exhibit higher levels of self-efficacy due to their recent training experiences, while in-service teachers may struggle with self-doubt due to accumulated classroom challenges. This difference suggests that the experiences of in-service teachers, which often include navigating diverse classroom dynamics and addressing varying student needs, may impact their confidence negatively.

Moreover, the training and coursework that pre-service teachers undergo often focus on modern pedagogical techniques and theories, which may include a variety of instructional strategies aimed at fostering student engagement and understanding. In contrast, in-service teachers may experience a disconnect between their training and

the realities of classroom teaching, leading to feelings of inadequacy or self-doubt. This finding aligns with Gavora (2010a) who asserted that pre-service teachers with high confidence demonstrate elevated motivation and enthusiasm towards studying mathematics, ultimately optimising their overall achievement in the subject. Addressing the self-confidence gap between pre-service and in-service teachers is crucial for improving mathematics instruction. Professional development initiatives could focus on providing in-service teachers with opportunities to enhance their pedagogical skills and build confidence through collaborative practices, mentorship, and reflective teaching experiences.

This suggests that pre-service teachers may place a greater emphasis on the importance and relevance of mathematics in their professional abilities. This finding resonates with Schoenfeld's (2002) argument that when students perceive mathematics as valuable and relevant to their lives, they are more likely to engage with mathematics and seek connections between mathematical concepts and real-world situations.

This observation is supported by findings from Boaler (2002), who found that students who view mathematics as a relevant and valuable discipline are more motivated to learn and are likely to develop a positive attitude toward the subject. The higher value attributed to mathematics by pre-service teachers could be a result of their recent academic experiences, where they are encouraged to explore the practical applications of mathematics in various contexts.

The perception of mathematics as a valuable discipline is vital for teachers, as it influences how they convey the subject's importance to their students (Wang et al., 2021). If teachers view mathematics as relevant and useful, they are more likely to inspire their students to appreciate the subject similarly. Similarly, on the parent/teacher expectations dimension, this dimension reflects the belief that mathematics helps develop critical thinking skills and is important in everyday life. The higher mean score for pre-service teachers could be attributed to their recent exposure to educational theories that emphasise the importance of mathematics in fostering cognitive development and problem-solving skills. This exposure often includes discussions about the role of parents and teachers in shaping students' perceptions and attitudes toward mathematics. These findings parallel research conducted by Gavora (2010b), which illustrated that teacher expectations play a

significant role in shaping students' attitudes and performance in mathematics. Understanding the expectations surrounding mathematics education is crucial for teachers as they guide their students. When teachers recognise the importance of their role in shaping students' attitudes toward mathematics, they can create an environment that encourages positive interactions with the subject.

4.3.3 Conclusion

The findings from this study provide insights into the attitudes of pre-service and in-service early-grade teachers toward mathematics in Ghana. Both groups demonstrated generally positive attitudes, with pre-service teachers reporting slightly higher mean scores across most dimensions. However, in-service teachers exhibited more positive attitudes on specific sub-scales, including enjoyment, confidence, and perceived value of mathematics. Additionally, the heightened awareness of parent and teacher expectations among in-service teachers suggests the impact of real-world teaching dynamics on shaping attitudes.

These results emphasise the importance of teacher education curricula in Ghana prioritising the cultivation of enjoyment, self-confidence, and recognition of the value of mathematics. It is equally critical to sustain and further nurture these positive attitudes as teachers progress in their careers. Integrating more practical teaching experiences within teacher education programmes could help pre-service teachers develop stronger attitudes toward mathematics, aligning more closely with their in-service counterparts.

The study also highlights the need for ongoing professional development opportunities to reinforce positive attitudes, address potential declines in confidence or enjoyment, and equip teachers with effective pedagogical strategies. Workshops focusing on promoting the value of mathematics in the classroom can help in-service teachers reinforce this perception among their students. By continuously supporting and nurturing positive attitudes among teachers, Ghana can foster effective teaching and learning experiences, ultimately empowering students to embrace and excel in mathematics.

4.4 Research Question 4

RQ4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?

The hypotheses guiding this research question are:

Hypothesis 1:

There will be a statistically significant relationship between pre-service and in-service teachers' attitudes towards mathematics and their teaching efficacy beliefs.

This hypothesis is grounded in the understanding that attitudes toward mathematics influence the development of teaching efficacy beliefs. For pre-service teachers, these beliefs are expected to be shaped significantly by their teacher education programs, including coursework and personal experiences with mathematics. In contrast, in-service teachers' efficacy beliefs are likely to be related to their direct teaching experiences, professional development opportunities, and feedback from their interactions with students. Despite these differing contexts, it is anticipated that a positive attitude toward mathematics correlates with stronger teaching efficacy beliefs in both groups.

Hypothesis 2:

There will be no statistically significant difference in the attitudes toward mathematics when comparing pre-service and in-service teachers.

This hypothesis assumes that attitudes toward mathematics are shaped by fundamental personal and educational factors that remain relatively stable over time, regardless of teaching experience. Both pre-service and in-service teachers are likely influenced by their prior experiences as students, their intrinsic interest in the subject, and their broader cultural and educational context. While in-service teachers may encounter challenges in their professional practice that could influence their attitudes, their foundational perspectives toward mathematics are not expected to differ significantly from those of pre-service teachers, who are still in the process of formal teacher preparation. This stability suggests that attitudes toward mathematics are less dependent on professional status and more closely related to individual dispositions and prior experiences with the subject.

4.4.1 Results

By testing this hypothesis, the study seeks to explore whether attitudes toward mathematics serve as a consistent predictor of teaching efficacy beliefs across both groups or whether teaching experience significantly modifies this relationship. Understanding these dynamics is important for designing interventions and training programs that strengthen teaching efficacy, particularly in contexts where attitudes toward mathematics may vary significantly between groups. The MTEB is composed of 13 items (2, 3, 5, 6, 8, 11, 15, 16, 17, 18, 19, 20, and 21) and Mathematics Teaching Outcome Expectancy (MTOE) sub-scale, which is composed of 8 items (1, 4, 7, 9, 10, 12, 13, and 14). Respondents were asked to indicate on a 4-point Likert scale the extent to which they agree or disagree with the list of statements pertaining to mathematics teaching efficacy beliefs. The mean score of the responses is compared with 2.5 (thus, $[1+2+3+4]/4 = 2.5$). A mean score above 2.5 indicates respondents agreed with the statement, whereas scores below 2.5 show that students disagreed with the statement. Details of pre-service and in-service teachers' mathematics teaching efficacy beliefs are found in Table 12 and Table 13, respectively.

Table 12: Pre-service Teachers' Mathematics Teaching Efficacy (N=344)

Statements	Mean	SD
When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort.	2.69	.70
I will continually find better ways to teach mathematics.	2.87	.71
Even if I try very hard, I will not teach mathematics as well as I will most subjects.	2.40	.76
When the mathematics grades of students improve, it is often due to their teacher having found a more effective teaching approach.	2.73	.74
I know how to teach mathematics concepts effectively.	2.74	.62
I will not be very effective in monitoring mathematics activities.	2.46	.72
If students are underachieving in mathematics, it is most likely due to ineffective mathematics teaching.	2.73	.65
I will generally teach mathematics ineffectively.	2.39	.77
The inadequacy of a student's mathematics background can be overcome by good teaching.	2.88	.69
When a low-achieving child progresses in mathematics, it is usually	2.74	.78

due to extra attention given by the teacher.		
I understand mathematics concepts well enough to be effective in teaching elementary mathematics.	2.65	.76
The teacher is generally responsible for the achievement of students in mathematics.	2.79	.64
Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching.	2.81	.72
If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher.	2.79	.73
I will find it difficult to use manipulatives to explain to students why mathematics works.	2.58	.69
I will typically be able to answer students' questions.	2.90	.64
I wonder if I will have the necessary skills to teach mathematics.	2.62	.67
Given a choice, I will not invite the principal to evaluate my mathematics teaching.	2.55	.71
When a student has difficulty understanding a mathematics concept, I will usually be at a loss as to how to help the student understand it better.	2.61	.72
When teaching mathematics, I will usually welcome student questions.	2.98	.68
I do not know what to do to turn students on to mathematics.	2.62	.70

Source: Field Survey, 2024

The result from Table 12 revealed that pre-service teachers agreed that when they are teaching mathematics, they will usually welcome student questions (M= 2.90, SD= .69); they also indicated that they will typically be able to answer students' questions. (M= 2.90, SD=.64). Moreover, they agreed that they would continually find better ways to teach mathematics (M= 2.87, SD= .71). However, pre-service teachers disagreed that they would generally teach mathematics ineffectively (M= 2.39, SD= .77) and disagreed that even if they try very hard, they will not teach mathematics as well as they will most subjects (M= 2.40, SD= .76). Generally, pre-service teachers were positive towards mathematics teaching efficacy beliefs.

Table 13: In-service Teachers' Mathematics Teaching Efficacy (N=78)

Statements	Mean	SD
When a student does better than usual in mathematics, it is often because the teacher exerted a little extra effort.	3.15	.67
I will continually find better ways to teach mathematics.	3.40	.61
Even if I try very hard, I will not teach mathematics as well as I will most subjects.	2.19	.84
When the mathematics grades of students improve, it is often due to their teacher having found a more effective teaching approach.	3.09	.89
I know how to teach mathematics concepts effectively.	2.97	.76
I will not be very effective in monitoring mathematics activities.	2.21	.84
If students are underachieving in mathematics, it is most likely due to ineffective mathematics teaching.	2.73	.75
I will generally teach mathematics ineffectively.	2.03	.95
The inadequacy of a student's mathematics background can be overcome by good teaching.	3.33	.71
When a low-achieving child progresses in mathematics, it is usually due to extra attention given by the teacher.	3.27	.80
I understand mathematics concepts well enough to be effective in teaching elementary mathematics.	2.92	.88
The teacher is generally responsible for the achievement of students in mathematics.	3.14	.77
Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching.	3.17	.92
If parents comment that their child is showing more interest in mathematics at school, it is probably due to the performance of the child's teacher.	3.27	.75
I will find it difficult to use manipulatives to explain to students why mathematics works.	2.44	.78
I will typically be able to answer students' questions.	3.15	.72
I wonder if I will have the necessary skills to teach mathematics.	2.81	.69
Given a choice, I will not invite the principal to evaluate my mathematics teaching.	2.41	.90
When a student has difficulty understanding a mathematics concept, I will usually be at a loss as to how to help the student understand it better.	2.79	.80
When teaching mathematics, I will usually welcome student questions.	3.44	.62
I do not know what to do to turn students on to mathematics.	2.42	.89

Source: Field Survey, 2024

From Table 13, the results indicate that in-service teachers agreed to statements that “When teaching mathematics, I will usually welcome student questions” (M= 3.44, SD= .62), “I will continually find better ways to teach mathematics” (M= 3.40, SD= .61), and “The inadequacy of a student's mathematics background can be overcome by good teaching” (M= 3.33, SD= .71). On the other hand, they disagreed that they would generally teach mathematics ineffectively (M= 2.03, SD= .95), and also disagreed that they would not be very effective in monitoring mathematics activities (M= 2.21, SD= .84). Overall, in-service teachers were positive towards mathematics teaching efficacy.

Test for Normality

As presented in Table 12 and Table 13 for pre-service and in-service teachers, respectively, the mean, median, and 5% trimmed mean of teachers attitudes towards mathematics and teaching efficacy beliefs of pre-service and in-service teachers were approximately equal. This indicates that the distributions of scores of the variables were normally distributed. The skewness and kurtosis were within the recommended ranges of (-2 to +2) and (-7 to +7), respectively (Hair et al., 2010). The normality test was necessary for the parametric test.

Table 14: Normality for Pre-service Teachers

Parameters	Attitude Towards Mathematics	Teaching Efficacy beliefs
Mean	80.95	53.33
Standard deviation	5.67	6.56
5% Trimmed mean	80.34	53.88
Median	79.00	54.00
Skewness	1.71	-1.12
Kurtosis	2.66	4.75

Source: Field Survey, 2024

Table 15: Normality for In-service Teachers

Parameters	Attitude Towards Mathematics	Teaching Efficacy beliefs
Mean	79.65	60.33
Standard deviation	3.87	6.83
5% Trimmed mean	79.17	60.29
Median	79.00	60.00
Skewness	1.80	.218
Kurtosis	5.68	.232

Source: Field Survey, 2024

4.4.2 The relationship between pre-service and in-service teachers' attitudes towards mathematics and their mathematics teaching efficacy beliefs

This objective aims to determine whether pre-service and in-service teachers' attitudes towards mathematics influence their mathematics teaching efficacy beliefs. The research hypothesis guiding this study is: There will be no statistically significant relationship between pre-service and in-service teachers' attitudes towards mathematics and their teaching efficacy beliefs.

The SEM path analysis used 1000 bootstrap samples and bias-corrected confidence intervals. The exogenous (predictor) variable was teachers' attitude towards mathematics, which was measured continuously. The criterion variable was mathematics teaching efficacy beliefs, which were also measured continuously. Details of the results are presented in Tables 16 and 17 and Figures 2 and 3.

Table 16: Regression Model for Pre-service Teachers Teaching Efficacy beliefs

Model	B	SE	CR	P	95% Confident Interval	
					Lower	Upper
(Constant)	39.73	5.01	7.81	.002	30.29	47.44
Attitude Towards Mathematics	.18	.90	4.79	.002	.08	.29

Significant, $p < .05$; $R^2 = .02$.

Criterion: Pre-service Teachers Mathematics Teaching Efficacy Beliefs

The results from Table 16 show that pre-service teachers' attitudes towards mathematics explained 2% of the variance in their teaching efficacy beliefs. The study further revealed that pre-service teachers' attitude towards mathematics $B = .18$, *Boot 95% CI* (.08, .29) was a significant predictor of their mathematics teaching efficacy beliefs. Pre-service teachers' attitudes towards mathematics positively predicted their mathematics teaching efficacy beliefs. This suggests a positive relationship between pre-service teachers' attitudes towards mathematics and their teaching efficacy beliefs.

Figure 2 presents the structural model of pre-service teachers' teaching efficacy beliefs. Furthermore, Table 17 and Figure 3 provide details of the influence of in-service teachers' attitudes towards mathematics on their teaching efficacy beliefs.

Table 17: Regression Model for In-service Teachers Teaching Efficacy Beliefs

Model	B	SE	CR	P	95% Confident Interval	
					Lower	Upper
(Constant)	54.55	5.01	7.81	.02	13.39	87.38
Attitude Towards Mathematics	.07	15.99	3.412	.67	-.34	.60

Significant, $p < .05$; $R^2 = .00$. Criterion: In-service Teachers Mathematics Teaching Efficacy beliefs

The results from Table 17 indicate that in-service teachers' attitudes towards mathematics explained 0% of the variance in their teaching efficacy beliefs. The study further revealed that in-service teachers' attitude towards mathematics $B = .07$, *Boot 95%CI* (-.34, .60) was not a significant predictor of in-service teachers' mathematics teaching efficacy beliefs. This means that in-service teachers' attitudes towards mathematics did not show a significant relationship with their mathematics teaching efficacy beliefs. (The Bootstrap 95% Confidence Interval (CI) is a statistical method used to estimate the range within which the true population parameter is likely to fall, with 95% confidence, based on a sample of data).

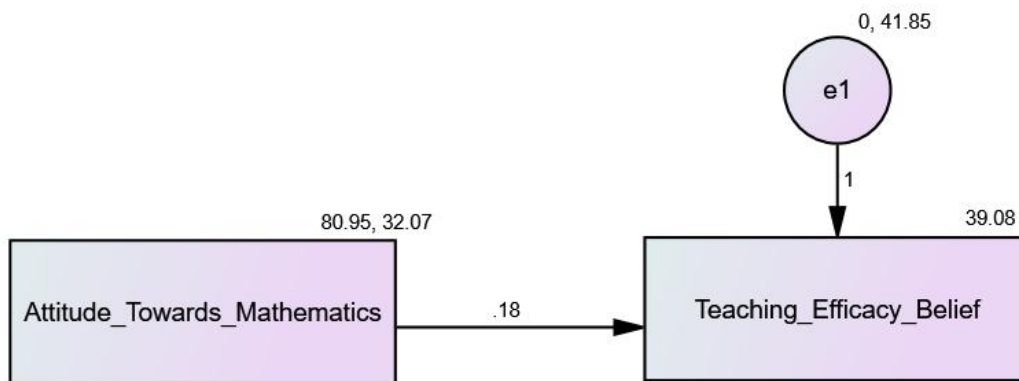


Figure 2: The structural model of in-service teachers' teaching efficacy beliefs

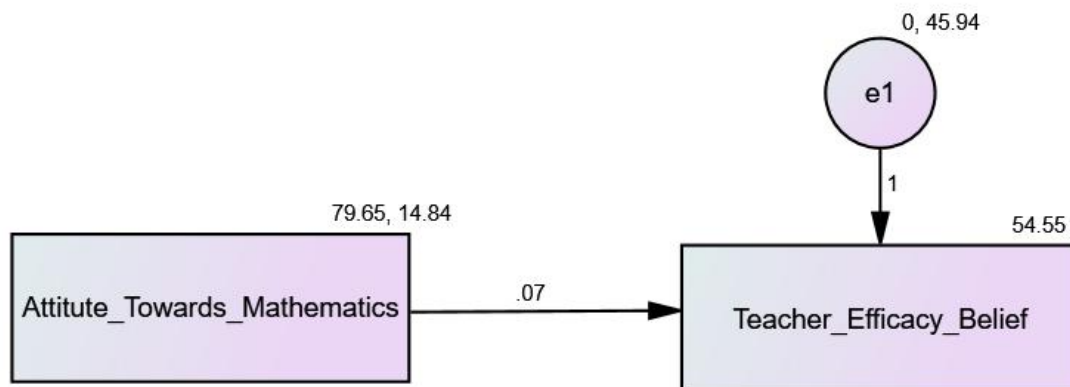


Figure 3: Path Model for Pre-service Teacher's Efficacy Beliefs

4.4.3 Pre-service Teachers and In-Service Teachers' Attitude Towards Mathematics

The aim was to test the difference in attitude towards mathematics between pre-service and in-service teachers. The objective was tested using an independent samples t-test. The independent variable was categorical: pre-service teachers and in-service teachers. The dependent variable was scored on attitude towards mathematics. The results are presented in Tables 18 and 19.

Table 18: Descriptive Statistics

Variable		M	SD
Attitude towards mathematics	Pre-service Teachers	52.9589	6.79744
	In- service Teachers	52.5385	7.59234

Source: Field Survey, 2024

Table 18 shows the descriptive statistics of the independent t-test. Furthermore, as shown in Table 19, Levene’s test of variance attitude towards mathematics ($p = .063$) did not violate the homogeneity assumption. With this independent sample t-test was conducted. The results of the independent sample t-test are presented in Table 14.

Table 19: Differences Between Pre-service and In-service Teachers on Attitude Towards Mathematics

Variable	Levene's Test for t-test for Equality of Means						
	Equality of Variances		t-test for Equality of Means				
	F	Sig.	T	df	Sig.	Diff.	S E
Attitude towards mathematics	3.472	.063	.506	420	.613	.42	.83

*Significant, $p < .05$

This objective sought to test whether pre-service teachers and in-service teachers differ in their attitudes towards mathematics. The results revealed no statistically significant difference in the attitudes of pre-service teachers ($M = 52.96$, $SD = 6.80$) and in-service teachers ($M = 52.54$, $SD = 7.59$, $t(420) = .51$, $p = .613$, $\eta^2 = .001$ (Table 15). The implication is that pre-service teachers and in-service teachers do not differ in their attitudes towards mathematics.

4.4.5 Discussion

The findings from this study provide valuable insights into the attitudes of pre-service and in-service early-grade teachers toward mathematics and their beliefs about

teaching effectiveness. One key observation is that the first hypothesis, which suggested a significant relationship between teachers' attitudes toward mathematics and their teaching efficacy, was confirmed only for pre-service teachers and not for in-service teachers. This indicates that while pre-service teachers' attitudes toward mathematics were strongly linked to their beliefs about their teaching effectiveness, this relationship did not hold for in-service teachers. This discrepancy could be due to the fact that in-service teachers, having accumulated a range of experiences, may have developed efficacy beliefs that are influenced by factors other than their attitudes toward mathematics. These experiences such as interactions with students, exposure to professional development opportunities, and the challenges faced in the classroom may have a more significant impact on their beliefs about their teaching effectiveness.

In contrast, pre-service teachers, who are still in the early stages of their careers and have fewer experiences to shape their beliefs, may find their attitudes toward mathematics to be a stronger predictor of their perceived teaching effectiveness.

4.4.5.1 Attitudes Toward Mathematics

Both pre-service and in-service teachers demonstrated generally positive attitudes toward mathematics, with no statistically significant differences between the two groups. This attitude consistency is consistent with prior research, which highlights the influence of teacher preparation programmes on shaping attitudes toward mathematics (Lutovac & Kaasila, 2014). However, for in-service teachers, their positive attitudes, particularly in the areas of enjoyment, confidence, and perceived value of mathematics, can be attributed to the impact of real-world teaching experiences. This finding aligns with research emphasising that practical experiences can reinforce confidence and commitment to teaching mathematics (Jančařík et al., 2023).

4.4.5.2 Mathematics Teaching Efficacy Beliefs

The significant relationship between pre-service teachers' attitudes towards mathematics and their teaching efficacy beliefs aligns with Bandura's (1997) self-efficacy theory, which posits that positive attitudes and beliefs enhance performance and confidence in specific domains. Pre-service teachers with favourable attitudes are likely to feel more capable of delivering effective mathematics instruction, as demonstrated by the predictive power of attitudes on efficacy beliefs in this study.

The lack of a significant relationship between attitudes and efficacy beliefs for in-service teachers suggests that other external factors play a crucial role in shaping their beliefs. Previous studies highlight the importance of classroom experiences, professional development, and school support systems in influencing teachers' efficacy beliefs (Segarra & Julià, 2020). These factors may include the challenges teachers face in the classroom, the available resources, and the professional networks they are part of, all of which contribute to their sense of effectiveness. This finding underscores the complexity of teaching efficacy in practice, where attitudes may form a foundational element but are not the sole determinants of teaching confidence and effectiveness (Moody & DuCloux, 2015). In-service teachers, having accumulated practical experience, may rely on these broader contextual factors to develop and refine their teaching efficacy, making it more complex and less directly linked to attitudes alone.

4.4.6 Conclusion

In conclusion, while both pre-service and in-service teachers exhibit positive attitudes towards mathematics, their influence on teaching efficacy beliefs differs. Pre-service teachers' attitudes significantly predict their efficacy beliefs, consistent with Bandura's self-efficacy theory. In contrast, in-service teachers rely more on practical experiences and external support systems, as highlighted in prior research.

These findings suggest the need for a dual focus in teacher education: cultivating positive attitudes in pre-service teachers and providing ongoing professional support for in-service teachers. This study contributes to the broader understanding of teacher attitudes and efficacy beliefs, offering practical implications for improving teacher education and professional development programs. Addressing these needs will enhance the effectiveness of mathematics instruction, ultimately benefiting student learning outcomes.

4.5 Research Question 5

The RQ 5: What level of Pedagogical Content Knowledge for teaching mathematics do early career teachers and pre-service early-grade teachers possess?

The findings of this have been published in Amusuglo (2024).

The hypothesis accompanying this research question was: There is no significant difference in the Pedagogical Content Knowledge between early career teachers and

pre-service early-grade teachers. This is organised into two phases: the qualitative and the quantitative phases.

To address this question, data was gathered using a teacher-made achievement test that assessed the PCK of the participating teachers.

4.5.1 Result of the Qualitative Phase

Table 20 shows the distribution of scores achieved by all grade teachers. This includes early career and pre-service teachers who participated in the study on their teacher-made achievement test. The test scores were classified into different categories. For this analysis, both groups of early career teachers and pre-service grade teachers will be referred to as grade teachers.

Table 20: Distribution of test scores and their respective frequencies and percentages.

Class	Frequency	Percentage
1 - 5	6	15
6 - 10	9	22.5
11 - 15	20	50
16 - 20	5	12.5
Total	40	100

Source: Field survey (2024)

Table 20 presents the frequencies and percentages corresponding to each group (both early career teachers and pre-service early-grade teachers) on the test scores. The scores of these grade teachers exhibited an average level of pedagogical content knowledge, ranging from 6 to 15 marks. Additionally, 12.5% of the grade teachers' test results showed exceptional performance. Their test results ranged between 16 and 20 marks; these grade teachers demonstrated a notably high level of pedagogical content knowledge. In comparison, these teachers showed commendable performance compared to others scoring below 10.

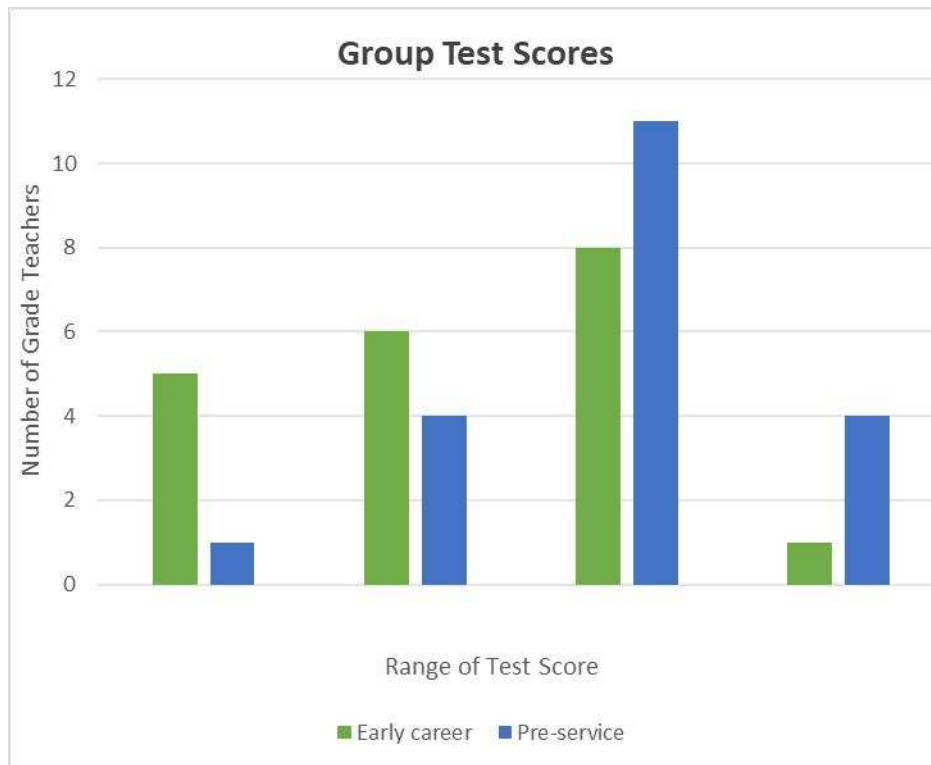


Figure 4: Distribution of test scores and their respective frequencies and percentages.

Most pre-service teachers scored within the highest range (11 to 15), indicating a stronger CK than their early career counterparts.

The scores for early career teachers are more evenly distributed across the ranges, with a notable number scoring in the lowest (1 to 5) and highest (11 to 15) ranges.

This data suggests that pre-service teachers performed better on the PCK test than early career teachers, with a higher concentration of pre-service teachers scoring in the top range.

4.5.2 Research Hypothesis:

The study was guided by the research hypothesis: There is no significant difference in the pedagogical content knowledge between early career and pre-service early-grade teachers. In order to address this research hypothesis, the achievement test results of both early career and pre-service mathematics schoolteachers were used. The independent sample t-test was used to analyse the data collected from two groups of grade teachers in a teacher-made achievement test on pedagogical content knowledge for teaching mathematics. The analysis was conducted using a significant level of 5%.

Table 21 presents the descriptive statistics for the test scores of the two groups of early-grade mathematics teachers.

Table 21: Descriptive statistics of test scores of grade teachers

	N	Range	Min	Max	Mean	Std Deviation	Std. Error Mean
Early Career teachers	20	13	3	16	9.20	4.20	.94
Pre-service	20	13	5	18	12.10	3.58	.80

Source: Field survey (2024)

The data shown in Table 21 indicates that among the 40 early-grade teachers who took part in the study, there were 20 early career grade teachers and 20 pre-service early-grade teachers. The table indicates that both groups of early-grade mathematics teachers possess an average level of pedagogical content knowledge (PCK) for teaching at the grade level.

The mean score of early career teachers was 9.20, with a standard deviation of 4.20. Meanwhile, the mean score of pre-service early-grade teachers was also 12.10, with a standard deviation of 3.58. The scores of early career grade teachers varied between 3 and 16, whereas the results of pre-service early-grade teachers ranged from 5 to 18. The aforementioned data about the range of test scores reveals that there is a difference in pedagogical content knowledge (PCK) between the two groups. However, pre-service early-grade teachers possess a relatively higher level of PCK knowledge compared to early career-grade teachers. The independent samples t-test can help determine if the difference in mean scores between early career and pre-service early-grade teachers is statistically significant. The summary statistics are shown in Table 22.

Table 22: Results of Independent Samples t-test on test scores of Early career and Pre-service early-grade teachers.

	Levene's Test for Equality of Variances	t-test for Equality of Mean
Equal variances assumed	2.32	1.36 -2.35 38 .024

Source: Field survey (2024)

4.5.3 Discussion

The test was conducted to assess whether there is a significant difference in their PCK knowledge. The findings indicate a statistically significant difference in pedagogical content knowledge between the two groups of grade teachers. Using the Shapiro-Wilk normality test, a sig value of .18 was obtained, which is greater than $\alpha = 0.05$. This implies that the data set has a normal distribution.

The mean score for early career grade teachers was 9.20, with a standard deviation of 4.20. On the other hand, pre-service early-grade teachers had a mean score of 12.10, with a standard deviation of 3.58. The p-value was .024, which is less than the significance level α of 0.05. Therefore, we reject the null hypothesis and conclude that there is a statistically significant difference in the pedagogical content knowledge of early career grade teachers and pre-service early-grade teachers. The statistically significant difference favours pre-service early-grade teachers. The observed difference in mean scores of the two groups of teachers is statistically significant. This indicates that pre-service early-grade teachers have a higher level of pedagogical content knowledge for teaching mathematics compared to early-career early-grade teachers. The findings indicate that pre-service early-grade teachers are more effective at teaching mathematics to students compared to early-career early-grade teachers. Additionally, this suggests that pre-service early-grade teachers can positively influence the mathematical thinking of primary school learners (Hagan et al., 2020; Martin, 2017).

4.5.4 Qualitative Phase Result

Interview Process

After the collection and analysis of the quantitative data, ten early-career teachers who had participated in the initial quantitative study were randomly selected for individual interviews. These teachers were contacted and invited to participate in the interviews, ensuring that the selected sample was diverse and representative of the broader group of early-career teachers involved in the study. The interviews followed a semi-structured format, which allowed for flexibility while maintaining focus on the key research questions. This approach facilitated an in-depth exploration of the teachers' experiences, beliefs, and perceptions regarding their Pedagogical Content Knowledge (PCK) development. The interview guide was designed based on the themes that had emerged from the quantitative analysis, ensuring that the questions were aligned with the study's objectives. The flexibility of the semi-structured approach enabled the interviewer to probe deeper into specific responses, ensuring comprehensive insights were gathered. The interviews aimed to explore five key themes related to PCK development, as identified in the quantitative phase:

Initial PCK Development: Teachers were asked to reflect on how their PCK initially developed when they began their teaching careers. This theme sought to understand the early-stage development of their teaching knowledge, exploring factors such as initial teacher training, early experiences in the classroom, and how they perceived their ability to teach mathematics at the outset of their careers.

Factors Influencing PCK Development: Participants discussed the various factors that have influenced their PCK development over time. These included personal factors (such as motivation and confidence), professional factors (like ongoing professional development, collaboration with colleagues, or mentoring), and contextual factors (including school environment, resources, and the nature of the student population). This theme aimed to capture the complex interaction of these factors in shaping teachers' mathematical teaching abilities.

Challenges in PCK Development: Teachers shared any challenges they encountered in developing their PCK. These challenges ranged from gaps in training (such as the

limited focus on specific teaching strategies in teacher preparation programs), lack of resources (including inadequate teaching materials and classroom support), to difficulties in implementing effective teaching strategies (such as addressing student misconceptions or creating engaging lessons). By exploring these challenges, the study aimed to identify common barriers faced by early-career teachers and provide insights into areas requiring improvement or additional support.

Strategies for PCK Improvement: Participants discussed the strategies they have employed to improve their PCK over time. These strategies included seeking professional development opportunities, participating in collaborative teaching practices, engaging in self-reflection, and adopting new teaching methods based on feedback and classroom experiences. The interviews explored how these strategies impacted their ability to enhance their teaching practices and how they integrated new knowledge into their everyday teaching.

Support Systems and Resources: Teachers also reflected on the support systems available to them, such as mentorship, professional development programs, and teaching resources. The aim was to explore how these support systems facilitated their PCK development and to identify what additional resources or support structures could better assist early-career teachers in their professional growth. Understanding the role of support systems in fostering PCK development was crucial for identifying the types of interventions that could improve teaching effectiveness in the early stages of a teaching career.

After the interviews were completed, the audio recordings were transcribed verbatim. The transcriptions were then analysed using thematic analysis, a qualitative research method that enabled the researchers to identify, analyse, and report patterns (themes) within the data. This approach provided a detailed and nuanced understanding of the participants' experiences and perceptions regarding their PCK development. Thematic coding was performed manually and with the assistance of Atlas.ti qualitative data analysis software to ensure consistency and reliability in identifying key themes. The data was reviewed multiple times to refine the themes and ensure that they accurately captured the nuances of the teachers' responses. These themes emerged as a result of this iterative process.

Themes	Sub-themes	Description
Limited Initial PCK	Initial PCK development	Early-career teachers often start with traditional methods focused on procedural knowledge, limiting students' engagement with mathematical concepts.
Initial PCK Development	Growth and adaptation	With experience, teachers adapt their methods, balancing procedural knowledge with conceptual understanding.
Factors Influencing PCK Development	Classroom experience Professional development Collaboration with colleagues Resource constraints Time pressures Large class sizes	<p>Practical classroom experience is key to developing PCK as it provides opportunities to test theories and refine strategies.</p> <p>Formal professional development helps teachers learn new strategies and improve their teaching methods.</p> <p>Collaboration with more experienced colleagues fosters peer learning and contributes to PCK development.</p> <p>Limited access to teaching resources restricts teachers' ability to implement diverse and innovative strategies.</p> <p>Teachers face time constraints due to the need to cover extensive curricula, leaving little room for reflection and improvement.</p> <p>Large class sizes make implementing individualised attention and varied teaching methods difficult.</p>

Strategies for PCK Improvement	Learner-centred approaches Real-world applications Collaborative learning Professional Development Opportunities	Teachers shift to learner-centred methods to engage students in discussion and critical thinking. Connecting mathematical concepts to real-world applications helps students see the relevance of mathematics. Teachers encourage student collaboration to enhance problem-solving and communication skills. Professional development sessions provide ongoing learning opportunities for teachers to stay updated with new methodologies.
Support Systems and Resources	Peer Support Need for Additional Resources	Teachers rely on peer support and department meetings to share best practices and troubleshoot challenges. Teachers express the need for more resources, including technology, to enhance student engagement and teaching effectiveness.

4.5.5 Discussion

The study on pedagogical content knowledge (PCK) for teaching mathematics among early career and pre-service early-grade teachers reveals several findings that align with and extend previous research in this area. The mixed-method approach, combining quantitative analysis with qualitative interviews, provides a comprehensive view of the development and challenges of PCK in early mathematics education.

The quantitative phase of the study revealed that both early career and pre-service early-grade teachers possess an average level of pedagogical content knowledge (PCK) for teaching mathematics. However, a significant difference was found between the two groups, with pre-service teachers demonstrating a higher level of PCK. This

finding somewhat contradicts the common assumption that classroom experience necessarily leads to higher PCK. This aligns with the work of (Borko, & Koellner 2010; Copur-Gencturk & Orrill 2023; Dogan Coskun & Isiksal Bostan 2022; Jacob et al., 2017 and Livy et al., 2019), who investigated the relationship between teaching experience and PCK among mathematics teachers. Their study highlighted that pre-service teachers, typically immersed in the most current research-based teaching methods and pedagogical training, often demonstrate stronger PCK than their early-career counterparts.

The findings suggest that while experience provides valuable classroom management skills and situational awareness, it does not always translate into higher PCK, especially when teachers are not engaging in continuous professional development focused on pedagogical skills. The qualitative phase of the study involved interviews with early career teachers, revealing five main themes: initial PCK development, factors influencing its growth, challenges in its development, strategies for improvement, and the role of support systems and resources.

4.5.6 Conclusion

The findings reveal that many early career teachers began with a traditional, procedural approach to mathematics teaching, focusing primarily on delivering subject matter knowledge through lectures, textbooks, and standard problem-solving exercises. This aligns with existing research that suggests early-career teachers often start with a limited view of pedagogical content knowledge (PCK), focused mainly on the transmission of knowledge rather than fostering a deeper understanding of mathematical concepts. However, as teachers gained more experience, they began to shift towards more conceptual teaching practices. This highlights the importance of providing early-career teachers with opportunities to reflect on their teaching methods and make the transition from procedural to conceptual approaches, which are crucial for fostering deeper student understanding (Depaepe et al., 2013; Montenegro 2020).

Classroom experience emerged as a critical factor in PCK growth, with participants emphasising that no amount of theoretical training could fully prepare them for the realities of the classroom. The experience of teaching, along with reflective practice, allowed teachers to adapt their methods and incorporate more conceptual teaching strategies. This finding aligns with (Depaepe et al., 2013 and Montenegro's 2020)

assertion that collaboration and hands-on experience play an essential role in building teaching knowledge. Teachers' exposure to real-world teaching scenarios facilitated their growth in understanding how to balance subject matter knowledge with pedagogical demands (Scheiner et al., 2019).

Resource limitations, time constraints, and large class sizes were consistently highlighted as significant challenges. These constraints often limit teachers' ability to implement learner-centred and conceptually rich teaching approaches. For example, the lack of sufficient teaching and learning materials, such as textbooks and technology, directly impacted teachers' ability to deliver high-quality instruction. The challenge of managing large class sizes further constrained efforts to adopt individualized and student-centred teaching methods, aligning with previous studies on the difficulties of teaching in resource-limited settings (Zuya et al., 2016; Rezat, Fan, & Pepin, 2021). These challenges highlight the need for systemic interventions to support teachers in overcoming these barriers.

Despite the challenges, teachers demonstrated a commitment to improving their PCK by adopting more learner-centred strategies and incorporating real-world applications into their lessons. This shift reflects a growing awareness of the importance of fostering conceptual understanding in students. For instance, one participant noted that integrating real-world applications into their lessons helped bridge the gap between abstract mathematical concepts and practical understanding. These strategies align with the literature on effective mathematics teaching, which advocates for a multi-dimensional approach that includes conceptual understanding, procedural fluency, and application (Dickerson et al., 2022). By actively seeking to improve their teaching methods, teachers showed adaptability and an openness to evolving their pedagogical practices.

Teachers identified the need for more resources, particularly regarding technology and teaching materials. This reflects ongoing challenges in many educational contexts where resource limitations are common. The potential for technology to enhance mathematics instruction has been well-documented in the literature (Naufel et al., 2021), and teachers in this study expressed a desire for greater access to these tools to support their PCK development. Additionally, professional development opportunities, peer support, and focused feedback were mentioned as essential for continuous growth. This aligns with research by Donnelly and Berry (2019), who argue that

ongoing professional development is key to supporting teachers in refining their PCK and addressing the challenges they face in the classroom.

Finally, this study contributes to our understanding of PCK development in early career and pre-service early-grade mathematics teachers. It highlights the interaction between theoretical knowledge, practical experience, and contextual factors in shaping teachers' PCK. The findings suggest that while pre-service education can provide a strong foundation in PCK, ongoing support, resources, and professional development opportunities are crucial for early career teachers to effectively apply and develop their PCK in classroom settings. This approach should cater to both the needs of individual teachers and the challenges within the system. Future research could explore the long-term trajectories of PCK development, the effectiveness of specific interventions in enhancing PCK, and strategies for overcoming resource constraints in challenging educational contexts.

CHAPTER FIVE – IMPLICATIONS, RECOMMENDATIONS, AND LIMITATIONS

Introduction

This chapter wraps up the study by analysing the findings presented in Chapter 4. Its primary aim is to explain how these findings address the research questions outlined in Chapter 1 and to discuss the study's contribution to the existing body of knowledge in relation to the current literature. It also offers future research and practice recommendations, highlighting areas that warrant further investigation. Finally, the chapter acknowledges the study's limitations, outlining potential constraints that may have influenced the findings and suggesting how these limitations could be addressed in future studies.

5.1 Revisiting the Study Purpose and Research Questions

When this study was conducted in 2024, there had been no prior investigation into the effects of curriculum reforms on the development of knowledge and skills in initial mathematics teacher education at the early-grade level. Several researchers (e.g., Eshun, 2004; Eshun-Famiyeh, 2005; Mereku, 2003) have explored mathematics classroom practices at the primary and senior secondary levels. However, not much work has focused specifically on early-grade teacher education. Therefore, the present study aimed to fill this gap by addressing several specific research questions (RQs).

RQ1: What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education in Ghana and the National Kindergarten Mathematics Curriculum?

RQ2: How do Ghana's national kindergarten and Colleges of Education early-grade mathematics curricula align with the knowledge and skills outlined by the Global Proficiency Framework?

RQ3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana?

RQ4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?

RQ5: What content and pedagogical content knowledge do early career teachers and pre-service early-grade teachers possess at the end of their College Education?

5.2 Summary of Findings

RQ1: What alignments exist between the early-grade mathematics curriculum implemented by Colleges of Education in Ghana and the National Kindergarten Mathematics Curriculum?

The analysis revealed that the content of the Ghanaian National KG Mathematics Curriculum aligns closely with the B.Ed. Early Grade Mathematics Curriculum. Both curricula cover similar mathematical topics, including numbers, algebra, geometry, measurement, and data handling, and incorporate key pedagogical strategies such as problem-solving, scaffolding, and play-based learning. The problem-solving approach emphasises conceptual understanding through engagement with complex, real-world problems. Scaffolding supports learners with varying abilities, ensuring inclusivity, while play-based learning is a central feature of the KG curriculum but is less detailed in the B.Ed. Curriculum.

The play-based activities are not embedded in the B.Ed. Early Grade Mathematics Curriculum. It is recommended that the Kindergarten (KG) Mathematics Curriculum be integrated into the B.Ed. Curriculum to equip pre-service teachers with practical, developmentally appropriate teaching methods for early-grade mathematics.

RQ2: Global Proficiency Framework: Analysis of National and Colleges of Education Curricula in Ghana.

The study identified a close alignment between Ghana's early-grade mathematics curriculum, the Colleges of Education curricula, and the Global Proficiency Framework (GPF). The national curriculum adheres to global standards by addressing key domains like numbers, algebra, and geometry. The Ghanaian curriculum introduces fractions in Grade 1, whereas the GPF introduces fractions in Grade 3. This proactive inclusion in the Ghanaian curriculum may help students build a deeper understanding of mathematical concepts at an earlier stage additionally, the B.Ed. Curriculum emphasises pedagogical strategies designed to equip teachers with the skills needed for effective mathematics instruction, further highlighting its compatibility with global expectations. This alignment suggests that the curricula

support students in achieving proficiency benchmarks comparable to international standards.

RQ3: What are pre-service and early career teachers' attitudes toward mathematics in Ghana?

The study seeks to understand the attitudes of pre-service and early career teachers toward mathematics, which can significantly impact their teaching practices and effectiveness. It explores factors influencing these attitudes, such as their experiences in mathematics education, perceptions of mathematics, and their confidence in teaching the subject.

The study's results reveal that both pre-service and in-service teachers generally have positive attitudes towards mathematics, showing agreement across areas like enjoyment, self-confidence, value, and expectations from parents and teachers. Pre-service teachers, still in training, displayed a slightly higher level of enjoyment in mathematics, which aligns with the idea that enjoyment is linked to positive emotional experiences in engaging with math.

A more significant gap was observed in the self-confidence dimension, with pre-service teachers showing higher confidence levels than in-service teachers. This difference may be due to pre-service teachers' limited experience with challenges in the field and their recent training in educational theories and methodologies, which boosts their confidence. Despite this gap, both groups expressed overall confidence in their math abilities, supporting the notion that self-confidence is linked to greater motivation and success in mathematics.

Pre-service teachers also placed slightly more importance on the value and relevance of mathematics in their professional lives and problem-solving skills. This higher valuation could be due to their recent exposure to educational approaches that emphasise the role of math in developing critical thinking. This finding aligns with the idea that perceiving mathematics as valuable encourages greater engagement and the ability to connect mathematical concepts with real-world applications.

RQ4: How do pre-service and in-service teachers' attitudes towards mathematics relate to their mathematics teaching efficacy beliefs?

This question examines how the attitudes of pre-service and in-service teachers toward mathematics are related to their beliefs about their efficacy in teaching the

subject and was guided by these hypothesis, *There will be a statistically significant relationship between pre-service and in-service teachers' attitudes towards mathematics and their teaching efficacy beliefs.*

This hypothesis is grounded in the understanding that attitudes toward mathematics are related to the development of teaching efficacy beliefs. For pre-service teachers, these beliefs are expected to be shaped significantly by their teacher education programs, including coursework and personal experiences with mathematics. In contrast, in-service teachers' efficacy beliefs were likely to be related to their direct teaching experiences, professional development opportunities, and feedback from their interactions with students. Despite these differing contexts, it is anticipated that a positive attitude toward mathematics correlates with stronger teaching efficacy beliefs in both groups.

There will be no statistically significant difference in the attitudes toward mathematics when comparing pre-service and in-service teachers.

This hypothesis assumes that attitudes toward mathematics are shaped by fundamental personal and educational factors that remain relatively stable over time, regardless of teaching experience. Both pre-service and in-service teachers are likely inclined by their prior experiences as students, their intrinsic interest in the subject, and their broader cultural and educational context. While in-service teachers may encounter challenges in their professional practice that could influence their attitudes, their foundational perspectives toward mathematics are not expected to differ significantly from those of pre-service teachers, who are still in the process of formal teacher preparation. This stability suggests that attitudes toward mathematics are less dependent on professional status and more closely related to individual dispositions and prior experiences with the subject.

RQ5: What content knowledge and pedagogical content knowledge do early career teachers and pre-service early-grade teachers possess at the end of their college education?

This research question investigates the depth and breadth of both Content Knowledge (CK) and Pedagogical Content Knowledge (PCK) that pre-service and early career teachers have acquired by the time they complete their college education. The focus is on understanding how well-prepared these teachers are to effectively teach

mathematics at the early-grade levels in Ghanaian Basic Schools. The study on Pedagogical Content Knowledge among early career and pre-service early-grade mathematics teachers used a mixed-method approach to explore the development and challenges of PCK. The quantitative analysis revealed that both groups have an average level of PCK, but pre-service teachers showed a higher level than early career teachers. This finding suggests that recent exposure to modern teaching methods during training gives pre-service teachers an advantage despite early career teachers having more classroom experience.

The qualitative phase identified themes such as initial PCK development, factors influencing growth, challenges faced, strategies for improvement, and the role of support systems. It was found that early career teachers initially focused on procedural teaching methods but shifted towards more conceptual approaches as they gained experience. Classroom experience and reflective practices were crucial in enhancing PCK, supporting the idea that hands-on teaching is vital for growth.

Challenges highlighted included resource limitations, time constraints, and large class sizes, which hindered the ability to adopt student-centred teaching methods. Despite these barriers, teachers were committed to improving their PCK by integrating real-world applications into lessons and adopting more learner-centred strategies. Teachers emphasised the need for better access to resources, technology, and continuous professional development.

A key limitation of the study was its small sample size, as it was conducted in only two districts with participants from four schools. Expanding the sample could provide a broader perspective and more generalizable results. Nonetheless, the findings align with existing research on PCK and the challenges in mathematics education.

5.3 Discussion

This study explores key aspects of early-grade mathematics education, focusing on the alignment of pre-service teacher education programmes with the Ghanaian National Kindergarten (KG) Mathematics Curriculum, teachers' attitudes toward mathematics, and their impact on teaching efficacy. It also examines the levels of content knowledge (CK) and pedagogical content knowledge (PCK) among pre-service and early-career teachers. The findings provide insights into critical areas

affecting the preparedness and effectiveness of mathematics teachers, highlighting both strengths and areas for improvement in teacher education and practice.

The study highlights a discrepancy between pre-service teacher education programmes and the Ghanaian National KG Mathematics Curriculum. Misalignment can hinder teachers' readiness to deliver effective mathematics instruction, potentially impacting the quality of education in early-grade classrooms by failing to equip them with the necessary instructional strategies and knowledge required for effective early mathematics teaching. Furthermore, the findings demonstrate that positive attitudes toward mathematics significantly influence teaching practices. Teachers with positive attitudes exhibit higher confidence and perceived teaching efficacy, creating more engaging and supportive learning environments. However, some participants expressed anxiety about their content knowledge and pedagogical strategies, suggesting that even generally positive attitudes toward mathematics may coexist with concerns about their ability to effectively teach the subject.

Teachers' attitudes toward mathematics directly affect their beliefs about teaching efficacy. Positive attitudes enhance teachers' confidence and ability to implement effective teaching practices, ultimately contributing to improved student mathematics outcomes. Finally, both pre-service and early-career teachers possess varying levels of CK and PCK. However, gaps remain in these areas, potentially limiting their ability to deliver effective and innovative mathematics instruction.

5.4 Conclusion

In conclusion, this study underscores the importance of aligning pre-service teacher education programmes with the Ghanaian National Kindergarten Mathematics Curriculum to ensure that teachers are well-prepared to deliver high-quality early-grade mathematics instruction. It highlights the significant role of teachers' attitudes toward mathematics in shaping their teaching efficacy and overall teaching practices. While positive attitudes can enhance confidence and teaching effectiveness, concerns about content knowledge and pedagogical strategies remain. The study also reveals that although both pre-service and early-career teachers demonstrate varying levels of content and pedagogical content knowledge, there are still critical gaps that need to be addressed to improve instructional quality. Ultimately, addressing these gaps and enhancing the alignment between teacher education and curriculum will be crucial for

fostering effective early mathematics education and ensuring that teachers are adequately equipped to meet the challenges of the classroom.

5.5 Recommendations

Strengthening mathematics education in early grades requires a robust foundation in teacher preparation and support. The findings of this study underline critical areas for improvement, including the alignment of pre-service education with the Ghanaian National Kindergarten (KG) Mathematics Curriculum, addressing teacher anxiety about mathematics, fostering positive attitudes toward the subject, and bridging gaps in both content knowledge (CK) and pedagogical content knowledge (PCK). To ensure teachers are adequately prepared to deliver effective mathematics instruction, targeted recommendations are essential to address these challenges and improve the quality of early-grade mathematics education.

One key recommendation is to enhance the alignment between pre-service teacher education programmes and the Ghanaian National KG Mathematics Curriculum. Integrating the KG curriculum into teacher training programmes would ensure that pre-service teachers are equipped with the knowledge and skills required to meet the expectations of the national curriculum. This integration would better prepare teachers to handle classroom realities and ensure a seamless transition from training to practice, ultimately improving instructional effectiveness and student outcomes.

Addressing teachers' anxiety about mathematics is another crucial area for intervention. The study found that some teachers expressed anxiety about their subject knowledge despite generally positive attitudes toward mathematics. Professional development initiatives should focus on reducing this anxiety by offering targeted training and support. Workshops and refresher courses could strengthen teachers' mathematical understanding, boost their confidence, and help them overcome any apprehensions related to teaching the subject.

Promoting positive attitudes toward mathematics is equally important. Teacher education programmes should include strategies to cultivate enthusiasm for the subject, such as integrating enjoyable, real-world problem-solving tasks and encouraging reflective practices. By fostering a positive mindset, teachers can inspire similar attitudes in their students, creating a more engaging and supportive learning

environment. Teachers with positive attitudes are not only more confident but also more likely to adopt innovative and effective teaching practices.

Content knowledge (CK) and pedagogical content knowledge (PCK) are vital for ensuring that teachers are well-prepared to deliver quality mathematics instruction. Colleges of Education should incorporate more comprehensive content and pedagogical training, emphasising practice-oriented courses and mentorship programmes. Providing access to classroom-based experiences during training would allow pre-service teachers to refine their instructional strategies and gain hands-on experience applying theoretical knowledge to real teaching contexts.

Furthermore, ongoing support for in-service teachers is essential for their continued growth and effectiveness. Continuous professional development opportunities should address challenges such as managing large classes and implementing learner-centred approaches. These programmes should enhance CK and PCK, enabling teachers to adapt to diverse classroom needs and maintain high-quality instruction throughout their careers.

In conclusion, these recommendations aim to address the key challenges identified in this study, fostering a stronger foundation for mathematics education in Ghanaian early-grade classrooms. By aligning teacher training with curriculum goals, addressing anxiety, promoting positive attitudes, and bridging knowledge gaps, these measures will ensure that teachers are better equipped to inspire and support young learners in their mathematical journey.

5.6 Limitations of the Study

One key limitation of this study was the relatively small sample size. The research was conducted in only two of the 170 districts in the country, with participants drawn from just four out of 102 basic schools in the two regions. While the sampling technique helped to maximise variation within the study sample, including additional districts would have allowed for a larger participant pool, providing a more representative view and enabling broader generalisation to a larger population. Despite this limitation, several findings from this study align with those of other researchers (e.g., Lakens, 2022; Cohen, & Morrison, 2000). Another limitation of this study is the absence of classroom observations, which would have provided direct insights into teachers' application of Pedagogical Content Knowledge (PCK) in real-

world instructional settings. Observing classroom practices could have revealed how teachers integrate their subject matter knowledge and pedagogy to address students' needs, manage misconceptions, and employ instructional strategies effectively. This would have offered a practical perspective on how teacher beliefs and efficacy translate into classroom actions, complementing the quantitative findings. Without this observational data, the study is limited in its ability to explore the practical manifestations of PCK, mainly how it interacts with teachers' attitudes and efficacy beliefs.

Qualitative data collection and analysis, such as interviews or focus groups, could have been included to provide deeper insights into the factors influencing these constructs. The absence of qualitative data limits the ability to capture nuanced perspectives and contextual influences that quantitative methods alone may not reveal.

5.7 Implication of the Findings

The findings of this study suggest substantial implications for improving the knowledge and skills necessary for initial mathematics teacher education and the early teaching experiences in Ghanaian Basic Schools.

Firstly, the higher PCK scores among pre-service teachers suggest that current teacher education programmes in Ghana effectively provide a strong theoretical foundation. However, the challenges reported by early career teachers indicate a need to bridge the gap between theory and practice. Teacher education programmes should incorporate more practical, classroom-based experiences to prepare teachers for the realities of Ghanaian classrooms.

Secondly, the identified challenges, particularly resource constraints and large class sizes, highlight the need for systemic support in Ghanaian education. Policymakers should prioritise providing adequate resources and addressing infrastructure issues to enable teachers to implement effective teaching strategies.

Thirdly, the importance of ongoing professional development and peer support suggests a need for structured mentoring programmes and regular in-service training opportunities in Ghanaian schools. These should focus on enhancing PCK, particularly in learner-centred approaches and integrating real-world applications in mathematics teaching.

Lastly, the expressed need for technological resources indicates an area for potential investment to support teachers' PCK development and enhance mathematics instruction in Ghanaian Basic Schools.

This research aimed to investigate how early-grade mathematics teachers develop knowledge and skills during their initial teacher education and early teaching years, with the goal of informing strategies to enhance the quality of mathematics education in Ghana. Through the methodological approach and data analysis, this research successfully achieved its aim of understanding the development of knowledge and skills among early-grade mathematics teachers in Ghana. There have been some suggested practical strategies to enhance the quality of mathematics education, contributing to improved learners' performance in mathematics in Ghanaian schools. Educational stakeholders can cultivate competent and confident mathematics educators by addressing the identified factors and implementing the suggested strategies.

In conclusion, this research has made a valuable contribution to mathematics education, particularly within the Ghanaian context, offering important insights for educators and stakeholders in the educational sector. The findings highlight issues for both teachers and policymakers, although teachers are aware of the new curriculum guidelines, there is a need for more professional development sessions that take into account the mathematics knowledge of both pre-service and in-service early-grade teachers. Organising these sessions will ensure that these guidelines are fully integrated into classroom practices. Taking these steps will enhance the quality of mathematics education and help achieve the curriculum's objectives in the classroom.

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