INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

Curriculum Reform Through the Lens of Mathematical Knowledge for Teaching: A Comparative Analysis of Ghana's Objective-Based and Standards-Based Senior High School Mathematics Curricula

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DOI: https://doi.org/10.51244/IJRSI.2026.1308000030

Received: 04 July 2026; Accepted: 09 July 2026; Published: 27 August 2026

ABSTRACT

Curriculum reform has become a central strategy for improving mathematics education, with increasing emphasis on conceptual understanding, problem solving, and twenty-first-century competencies. In Ghana, the transition from the 2010 Objective-Based Curriculum to the 2023 Standards-Based Curriculum for Senior High School mathematics represents a significant shift in curriculum philosophy, instructional expectations, and intended learning outcomes. Although previous studies have examined teachers' perceptions and implementation challenges, limited attention has been given to how the reform has reshaped the mathematical knowledge expected of teachers. This study employed qualitative document analysis to compare the two curricula through the six domains of Mathematical Knowledge for Teaching: Common Content Knowledge, Specialized Content Knowledge, Horizon Content Knowledge, Knowledge of Content and Students, Knowledge of Content and Teaching, and Knowledge of Content and Curriculum. The curriculum documents were coded deductively using ATLAS.ti, and the resulting frequencies were interpreted alongside qualitative evidence from the documents. The findings indicate that both curricula place substantial emphasis on teachers' mathematical knowledge, but the Standards-Based Curriculum makes a broader range of pedagogical and interpretive knowledge demands explicit. Pedagogical Content Knowledge increased from 29.1% of coded instances in the Objective-Based Curriculum to 43.3% in the Standards-Based Curriculum. The later curriculum also makes mathematical connections, attention to learners' prior knowledge, inquiry-based instruction, collaboration, inclusive pedagogy, and practical application more visible. The findings suggest that successful curriculum implementation requires more than the publication of a revised curriculum document. Teacher education and professional development must deliberately strengthen teachers' Mathematical Knowledge for Teaching so that they can interpret and enact the broader expectations embedded in the Standards-Based Curriculum. The study contributes to research on curriculum reform by demonstrating how the MKT framework can be used to examine changes in the professional knowledge expected of mathematics teachers.

Keywords: Mathematical Knowledge for Teaching, curriculum reform, mathematics curriculum, teacher knowledge, Ghana.

INTRODUCTION

Curriculum reform has become a defining feature of mathematics education worldwide as education systems seek to prepare learners for the demands of an increasingly complex and knowledge-driven society. In recent decades, many countries have revised their mathematics curricula to move beyond procedural competence and rote memorization toward approaches that emphasize conceptual understanding, problem solving, critical thinking, collaboration, and the application of mathematics to authentic contexts. These reforms reflect the growing recognition that success in the twenty-first century requires learners to develop not only mathematical proficiency but also the ability to reason, communicate, and apply mathematical ideas in diverse situations.

Like many countries, Ghana has undertaken substantial reforms to improve mathematics education at the pre-tertiary level. The transition from the Objective-Based Curriculum (OBC) to the Standards-Based Curriculum (SBC) for Senior High School (SHS) mathematics represents one of the most significant curriculum reforms in the country's educational history. While the OBC primarily organized learning around specific objectives and teacher-directed instruction, the SBC adopts a competency-based approach that emphasizes learner-centered pedagogy, conceptual understanding, real-world application, and the development of twenty-first-century skills. The reform therefore represents more than a revision of curriculum content; it reflects a broader shift in how mathematics teaching and learning are conceptualized.

The success of any curriculum reform, however, depends not only on the quality of the curriculum document but also on teachers' capacity to interpret and enact its intentions in the classroom. Effective mathematics teaching requires knowledge that extends beyond mastery of mathematical content. Teachers must be able to anticipate students' misconceptions, select appropriate representations, connect mathematical ideas across topics, and design instructional experiences that promote meaningful learning. These forms of knowledge are collectively described within the Mathematical Knowledge for Teaching (MKT) framework developed by Ball, Thames, and Phelps (2008), which conceptualizes the specialized mathematical knowledge required for effective teaching. Consequently, curriculum reforms that introduce new instructional expectations inevitably reshape the knowledge demands placed on teachers.

Although Ghana's curriculum reform has attracted increasing scholarly attention, existing studies have largely focused on teachers' perceptions of the new curriculum, implementation challenges, and the adoption of learner-centered pedagogies. Comparatively little attention has been devoted to examining how the reform itself has transformed the mathematical knowledge expected of teachers. In particular, there has been no systematic comparison of the OBC and SBC mathematics curricula through the lens of Mathematical Knowledge for Teaching. Understanding these changes is important because curriculum documents communicate not only what students are expected to learn but also the forms of teacher knowledge necessary to support that learning.

This study examines Ghana's curriculum reform through the framework of Mathematical Knowledge for Teaching (MKT). Specifically, it compares the 2010 Objective-Based Senior High School Mathematics Curriculum and the 2023 Standards-Based Senior High School Mathematics Curriculum to investigate how the transition between the two reforms has reshaped the mathematical and pedagogical knowledge expected of teachers. By applying the MKT framework to curriculum analysis, the study extends existing research beyond teacher perceptions and implementation challenges to examine the knowledge demands embedded within the curriculum documents themselves.

The study was guided by the following research questions:

1. How is Mathematical Knowledge for Teaching represented in Ghana's 2010 Objective-Based and 2023 Standards-Based Senior High School Mathematics curricula?

2. How has the transition from the Objective-Based Curriculum to the Standards-Based Curriculum changed the Mathematical Knowledge for Teaching embedded within the curriculum?

3. What implications do these changes have for mathematics teachers, teacher education, and future curriculum development in Ghana?

By addressing these questions, this study makes three important contributions to the literature. First, it provides the first systematic comparison of Ghana's 2010 Objective-Based and 2023 Standards-Based Senior High School Mathematics curricula through the framework of Mathematical Knowledge for Teaching. Second, it demonstrates how curriculum reform can be examined not only in terms of content or implementation but also through the evolving knowledge demands placed on teachers. Finally, the findings provide evidence that can inform curriculum design, teacher preparation, professional development, and future mathematics education reforms in Ghana and other educational contexts undertaking competency-based curriculum reforms.

LITERATURE REVIEW

Mathematics Curriculum Reform

Curriculum reform has become a defining characteristic of mathematics education across the world as governments and educational agencies seek to prepare learners for the demands of rapidly changing societies. Advances in technology, globalization, and the increasing need for critical thinking and problem-solving have challenged traditional approaches to mathematics instruction that emphasized procedural fluency and memorization. Consequently, many countries have undertaken comprehensive reforms aimed at developing learners who are capable of reasoning mathematically, communicating ideas effectively, applying mathematical concepts to authentic situations, and adapting to increasingly complex social and economic environments. Rather than viewing mathematics as a collection of isolated procedures, contemporary curriculum reforms encourage learners to develop conceptual understanding and flexible problem-solving abilities that can be transferred across contexts.

Although the goals of curriculum reform are often similar across countries, the approaches adopted and the challenges encountered vary considerably. A common feature of recent reforms is the transition from content-driven curricula toward competency-based or standards-based curricula that place greater emphasis on learner participation, inquiry, collaboration, and the development of higher-order thinking skills. These reforms also redefine the role of teachers, shifting instructional practice from teacher-centred transmission of knowledge to facilitating learning environments in which students actively construct mathematical understanding. Such changes inevitably require teachers to adopt new pedagogical approaches and to develop forms of professional knowledge that extend beyond mastery of mathematical content.

Evidence from international research demonstrates that designing an innovative curriculum does not necessarily guarantee successful classroom implementation. Johnson and Fitzmaurice (2025), for example, investigated the implementation of Ireland's Leaving Certificate Higher Level mathematics curriculum, a reform intended to promote inquiry-based learning, conceptual understanding, and mathematical problem solving. Using document analysis and teacher interviews, they found that although teachers generally supported the objectives of the reform, implementation was constrained by limited instructional time, examination pressures, and the diverse mathematical preparedness of students. These challenges often resulted in teachers reverting to more traditional instructional approaches despite the curriculum's emphasis on inquiry and student engagement. Their findings highlight an important lesson for curriculum reform: meaningful educational change depends not only on the design of curriculum documents but also on teachers' ability to interpret and enact their intentions within real classroom contexts.

The Irish experience reflects a broader pattern reported across many educational systems. Curriculum reform frequently introduces ambitious expectations for teaching and learning, yet the extent to which these expectations are realized depends largely on teachers. Curriculum documents may prescribe new instructional philosophies, but teachers ultimately determine how those philosophies are translated into classroom practice. Consequently, understanding curriculum reform requires attention not only to what curriculum documents prescribe but also to the forms of knowledge that teachers must possess to implement those prescriptions effectively. This perspective provides the foundation for examining curriculum reform through the lens of Mathematical Knowledge for Teaching, which offers a framework for understanding the specialized knowledge required to translate curriculum intentions into meaningful mathematical learning experiences.

Mathematics Curriculum Reform in Ghana

The development of school mathematics in Ghana is closely connected to the country's broader educational history. During the colonial period, mathematics at the elementary level was taught largely as arithmetic, with emphasis on number facts, tables of measurement, domestic arithmetic, computational accuracy, and the use of formulae. Many of the textbooks used at the time had been developed for schools in Britain and were subsequently adopted in British colonies such as the Gold Coast. This approach established mathematics as an important school subject, but it also encouraged a culture of memorization, repeated practice, speed, and procedural accuracy rather than conceptual understanding (Mereku, 2010).

Following Ghana's independence in 1957, education became an important instrument for national development, and the inherited colonial curriculum increasingly came under review. During this period, international developments in mathematics education, particularly the emergence of "modern mathematics" or "new math," began to influence curriculum reform in Ghana and other African countries. These developments emphasized mathematical structures, sets, functions, and formal mathematical language. One important initiative was the African Mathematics Programme, which emerged following a conference of African ministers of education held in Accra in 1961. The programme sought to modernize mathematics education across English-speaking African countries, but it was criticized because much of its content was developed by university academics and external specialists rather than practicing classroom teachers. Some of its language, examples, and abstract concepts were also difficult for teachers and learners to interpret within local contexts (Mereku, 2010).

Later initiatives attempted to produce curriculum materials that were more responsive to Ghanaian educational needs. These included the Joint Schools Project, which developed materials for secondary schools in West Africa, and the Ghana Mathematics Series, which was used in primary schools, teacher-training colleges, and later junior secondary schools. Although these materials promoted discovery approaches and meaningful learning, the classroom activities needed to support such approaches were not always sufficiently developed. Consequently, many teachers continued to depend on direct explanation, computation, memorization of formulae, and repetitive exercises (Mereku, 2010).

The 1974 and 1987 educational reforms marked further stages in the development of Ghana's education system. In particular, the 1987 Educational Reform Programme reorganized pre-tertiary education and expanded the school mathematics curriculum. Topics such as number bases, sets of numbers, probability, statistics, vectors, and transformational geometry received greater attention. However, the introduction of new mathematical content was not always accompanied by adequate preparation for teachers. Many teachers experienced difficulty understanding and teaching some of the newly introduced topics, particularly where the intended pedagogy differed from the instructional approaches with which they were familiar. This experience reinforced a recurring challenge in Ghanaian curriculum reform: changes in curriculum content often placed new demands on teachers without providing sufficient support for implementation (Mereku, 2010).

Further educational reforms were introduced in 2007, continuing Ghana's efforts to improve the structure, relevance, and outcomes of pre-tertiary education. At the Senior High School level, these developments eventually led to the introduction of the Teaching Syllabus for Senior High School Core Mathematics in 2010. This document, referred to in the present study as the Objective-Based Curriculum (OBC), was developed by the Curriculum Research and Development Division of the Ghana Education Service. Its stated rationale was to enable Ghanaian learners to acquire the mathematical skills, knowledge, attitudes, and values required for their future careers and everyday lives (Ministry of Education, 2010).

The 2010 OBC organized the three-year Senior High School mathematics programme around units, specific objectives, mathematical content, teaching and learning activities, and evaluation. Each specific objective described what students were expected to be able to do during or after instruction, while the teaching and learning activities provided guidance on how teachers might support those objectives. The curriculum also encouraged teachers to create opportunities for student participation and to ensure that learners understood and applied the mathematical ideas presented. Nevertheless, its structure positioned the teacher as the central organizer and director of instruction. The prescribed activities frequently used expressions such as "guide students," "assist students," "review with students," and "discuss with students," reflecting a largely teacher-directed approach to curriculum enactment.

Although the OBC included goals related to understanding, application, and problem solving, concerns remained about the dominance of examination-oriented teaching, procedural learning, and teacher-centred pedagogy in Ghanaian mathematics classrooms. Agbozo, Bonyah, and Clark (2024) observe that Ghana has experienced repeated reforms, including those introduced after independence and in 1974, 1987, 2007, and 2020, yet changes in pedagogy have not always kept pace with changes in curriculum content. They argue that teacher-centred approaches have remained common and have often presented mathematics to learners as a collection of rules, procedures, and disconnected facts rather than as a meaningful and culturally situated discipline.

The most recent phase of curriculum reform began with national discussions in 2017 and the development of policy documents such as the Education Strategic Plan, the National Pre-Tertiary Education Curriculum Framework, and the National Pre-Tertiary Learning Assessment Framework. The reform was introduced gradually, beginning with Kindergarten and Primary School curricula in 2019 and extending to Junior High School by 2021. The process later moved to Senior High School, culminating in the publication of the Mathematics Curriculum for Secondary Education in 2023. This document is referred to in the present study as the Standards-Based Curriculum (SBC). The SHS curriculum was publicly introduced in 2023 and began implementation in 2024.

The 2023 SBC represents a significant departure from the organization and philosophy of the OBC. Rather than structuring learning primarily around specific objectives, it is organized around strands, sub-strands, content standards, learning outcomes, learning indicators, pedagogical exemplars, and assessment. It emphasizes conceptual understanding, learner participation, critical thinking, creativity, collaboration, communication, digital literacy, problem solving, real-life application, and the acquisition of twenty-first-century competencies. It also incorporates gender equality and social inclusion, social-emotional learning, and shared national values. The curriculum explicitly calls for a movement away from rote memorization and passive learning toward active, inquiry-based, project-based, collaborative, and learner-centred pedagogy.

This shift has important implications for teachers. Under the SBC, teachers are expected not only to present mathematical content but also to create learning environments in which students investigate ideas, communicate their reasoning, make connections, solve unfamiliar problems, use technology, work collaboratively, and apply mathematics in practical contexts. The reform therefore introduces broader expectations concerning teachers' mathematical, pedagogical, curricular, and interpretive knowledge. In this respect, the transition from the OBC to the SBC represents not simply a change in curriculum structure but a redefinition of what it means to teach mathematics effectively in Ghanaian Senior High Schools.

Studies conducted in Ghana provide useful evidence about how teachers have responded to standards-based reform. Aboagye and Yawson (2020) examined teachers' perceptions of Ghana's new curriculum and found that participants generally viewed the reform positively. Teachers believed that the curriculum encouraged group work, promoted lifelong skills, prepared students for the workplace, supported inclusive education, and reflected the social and cultural experiences of Ghanaian learners. However, they also reported significant implementation challenges, including inadequate teaching and learning materials, increased workload, insufficient preparation, and limited teacher involvement in curriculum planning. The participants recommended that future reforms should involve teachers more directly, provide training before implementation, ensure that instructional resources are available, and pilot new curricula before national rollout.

Aboagye and Yawson's findings also raised concerns about technological readiness. Many teachers were unable to access the online questionnaire used in the study, and those who participated were predominantly younger teachers. This observation is relevant because the standards-based reform places greater emphasis on technology and digital literacy. It suggests that expectations concerning technology use may not be realized uniformly unless teachers have both access to digital resources and the competence required to use them effectively.

Addai-Mununkum and Setordzi (2023) similarly investigated Ghanaian teachers' experiences with implementing twenty-first-century pedagogies. Their study found evidence that some teachers had begun adopting approaches such as lesson starters, cooperative learning, inquiry-based learning, experiential activities, student discussion, and group presentation. These practices were consistent with the learner-centred philosophy of the new curriculum and created opportunities for students to participate more actively in their own learning.

However, implementation was uneven. Some teachers had limited knowledge of the curriculum reform or did not clearly understand important elements such as its core competencies. Others expressed uncertainty about how to enact learner-centred approaches in practice, even after participating in professional training. Teachers also identified inadequate instructional resources, limited time, increased workload, and insufficient training as major challenges. Addai-Mununkum and Setordzi found that only a small proportion of their participants could be described as innovators who readily embraced the reform, while most struggled to move away from familiar practices developed under the previous curriculum.

Taken together, these Ghanaian studies show that teachers generally appreciate the goals of standards-based reform but encounter significant difficulties translating those goals into classroom practice. They also demonstrate that implementation is influenced by teachers' knowledge, skills, beliefs, preparedness, access to instructional resources, and willingness to adopt unfamiliar pedagogical approaches. The studies therefore reinforce a central lesson from Ghana's history of curriculum reform: revising the written curriculum is only one part of educational change. The successful implementation of reform also depends on whether teachers possess the professional knowledge required to interpret curriculum expectations and transform them into meaningful mathematical learning experiences.

The transition from the 2010 Objective-Based Curriculum to the 2023 Standards-Based Curriculum should therefore be understood as part of a longer history of curriculum reform in Ghana. Earlier reforms sought to modernize mathematical content, whereas more recent reforms have placed increasing emphasis on conceptual understanding, application, learner participation, and twenty-first-century competencies. Each stage has also increased the demands placed on mathematics teachers. Examining the OBC and SBC through the lens of Mathematical Knowledge for Teaching makes it possible to identify how these demands have changed and to consider the implications of that change for teacher education and professional development.

Mathematical Knowledge for Teaching

Effective mathematics teaching requires more than the ability to solve mathematical problems correctly. A teacher may possess strong disciplinary knowledge and still experience difficulty explaining why a procedure works, interpreting an unexpected student solution, selecting an appropriate representation, or anticipating the misconceptions students are likely to develop. Teaching therefore depends on forms of knowledge that are closely connected to the practical work of helping others understand mathematics.

The foundations of this view can be traced to Shulman's (1986) work on teacher knowledge. Shulman argued that research on teaching had paid considerable attention to classroom management, lesson organization, assessment, and general pedagogical practice while giving insufficient attention to the subject matter being taught. He described this omission as a "missing paradigm" and sought to explain how teachers transform disciplinary knowledge into forms that learners can understand. His framework distinguished among subject matter knowledge, pedagogical content knowledge, and curricular knowledge.

Subject matter knowledge refers to a teacher's understanding of the concepts, structures, principles, and methods of justification within a discipline. In mathematics, this includes knowing not only how to obtain a correct answer but also why a mathematical claim is valid, how concepts are related, and what forms of reasoning support them. Pedagogical content knowledge concerns the transformation of subject matter for teaching. It includes knowledge of useful explanations, examples, analogies, representations, demonstrations, and ways of responding to learners' misconceptions. Curricular knowledge refers to familiarity with the materials, programmes, topics, and instructional resources available for teaching, including knowledge of how content is organized across grade levels and subject areas (Shulman, 1986).

Building on Shulman's work, Ball, Thames, and Phelps (2008) developed the framework of Mathematical Knowledge for Teaching (MKT). Their aim was to identify more precisely the mathematical knowledge used in the actual work of teaching. Rather than treating teacher knowledge as equivalent to the mathematics learned in advanced coursework, they examined tasks that arise specifically in classrooms, such as evaluating alternative solution methods, interpreting student errors, determining whether an explanation is mathematically valid, choosing examples that reveal important features of a concept, and connecting current instruction to earlier and later mathematical ideas.

Ball et al. (2008) defined MKT as the mathematical knowledge required to perform the recurring tasks involved in teaching mathematics. The framework is organized into two broad categories: Subject Matter Knowledge and Pedagogical Content Knowledge. Subject Matter Knowledge consists of Common Content Knowledge, Specialized Content Knowledge, and Horizon Content Knowledge. Pedagogical Content Knowledge consists of Knowledge of Content and Students, Knowledge of Content and Teaching, and Knowledge of Content and Curriculum. These six domains are conceptually distinct, but they frequently operate together during instruction.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

Common Content Knowledge

Common Content Knowledge (CCK) refers to mathematical knowledge and skills used in teaching but not unique to the teaching profession. It includes carrying out calculations correctly, applying standard algorithms, recognizing incorrect answers, using mathematical notation accurately, and solving the types of problems included in the curriculum. Other mathematically educated adults may also possess this knowledge; what makes it relevant to teachers is that they must use it reliably while planning, explaining, and evaluating students' work.

CCK forms an essential foundation for teaching because teachers must understand the mathematics they are expected to teach. However, knowing how to solve a problem is not sufficient for responding to all the demands of classroom instruction. A teacher may know the correct procedure without being able to explain its mathematical basis, compare several methods, or determine why a student produced an incorrect response. These additional tasks require more specialized knowledge.

Specialized Content Knowledge

Specialized Content Knowledge (SCK) is mathematical knowledge that is particularly important for teaching and is not ordinarily required in other settings. It includes examining unfamiliar solution methods, assessing whether a student's reasoning is mathematically valid, identifying the source of an error, providing mathematical explanations, selecting examples that highlight important properties, and representing concepts in multiple ways.

For example, solving a quadratic equation correctly may draw primarily on CCK. Explaining why different methods of solving the equation are equivalent, interpreting a student's nonstandard approach, or choosing examples that expose the relationship between algebraic and graphical representations requires SCK. This domain is central to the work of teaching because teachers routinely encounter reasoning that differs from the method they initially expected.

The distinction between CCK and SCK is especially important in curriculum analysis. A curriculum may require students to perform a mathematical procedure, thereby implying a need for CCK. It may also require teachers to explain, justify, compare, represent, investigate, or generalize mathematical ideas, thereby placing greater demands on SCK. Examining these differences helps reveal whether a curriculum positions teaching mainly as the delivery of established procedures or as the facilitation of deeper mathematical understanding.

Horizon Content Knowledge

Horizon Content Knowledge (HCK) refers to an awareness of how mathematical ideas are connected across topics, grade levels, and the wider discipline. It enables teachers to understand how the content currently being taught relates to ideas students encountered previously and to concepts they will study later. HCK also includes recognizing connections among different areas of mathematics and understanding how a particular topic contributes to a larger mathematical structure.

A teacher with strong HCK can avoid presenting topics as isolated units and can help students develop a coherent understanding of mathematics. For example, proportional reasoning may be connected to fractions, rates, similarity, linear relationships, probability, and later algebraic thinking. Awareness of these relationships allows the teacher to select explanations and activities that build toward future learning rather than treating each lesson as self-contained.

HCK is particularly relevant to curriculum reform because a standards-based curriculum often emphasizes mathematical connections, progression, interdisciplinary application, and transfer of learning. When curriculum documents ask learners to connect ideas across strands or apply prior knowledge in new contexts, they implicitly require teachers to understand the broader mathematical landscape in which those ideas are situated.

Knowledge of Content and Students

Knowledge of Content and Students (KCS) combines mathematical understanding with knowledge of how students think about and learn particular content. It includes anticipating which ideas students may find difficult, recognizing common misconceptions, interpreting incomplete or incorrect reasoning, predicting how students are likely to approach a task, and identifying examples that may be especially accessible or confusing.

KCS is neither general knowledge of learners nor mathematical content knowledge alone. It lies at the intersection of the two. For instance, a teacher may know the mathematical meaning of a negative sign but also need to understand why students frequently confuse subtraction, negative numbers, and additive inverses. Similarly, when selecting a task, a teacher may need to anticipate whether students will rely on an overgeneralized rule or interpret a representation in an unintended way.

This domain becomes increasingly important in learner-centred curricula because teachers are expected to build instruction from students' prior knowledge, responses, misconceptions, and emerging reasoning. A curriculum that encourages differentiated teaching, inquiry, discussion, and attention to learners' experiences places stronger demands on teachers' KCS than one that mainly specifies content to be presented.

Knowledge of Content and Teaching

Knowledge of Content and Teaching (KCT) concerns the relationship between mathematics and instructional design. It includes knowing how to sequence examples, select representations, choose tasks, organize classroom discussion, decide when to introduce formal notation, and determine which teaching approach is most appropriate for a particular mathematical idea.

KCT requires teachers to make judgments about both content and pedagogy. For example, several representations of a function may be mathematically correct, but a teacher must decide which representation should be introduced first, how students should move among them, and what questions may draw attention to important relationships. Likewise, a mathematical task may be suitable for group investigation, direct explanation, practical activity, or technology-supported exploration depending on the intended learning outcome.

The distinction between KCS and KCT is useful but not always absolute. Anticipating a misconception draws mainly on KCS, while deciding how to address it draws more strongly on KCT. In classroom practice, the two often work together as teachers interpret students' thinking and make instructional decisions in response.

Knowledge of Content and Curriculum

Knowledge of Content and Curriculum (KCC) refers to teachers' understanding of how mathematical content is organized within official curricula, programmes, textbooks, assessments, and instructional materials. It includes knowing what topics are expected at a particular grade level, how content progresses over time, what resources are available, and how instructional goals align with assessment expectations.

KCC allows teachers to situate individual lessons within the larger curriculum. It supports decisions about pacing, sequencing, revision, prerequisite knowledge, and alignment with national standards. It also helps teachers recognize whether a task or representation is appropriate for the level at which it is being introduced.

This domain is directly relevant to the present study because the two curriculum documents do more than list mathematical topics. They organize content differently, describe different learning expectations, and provide different forms of pedagogical and assessment guidance. Comparing them through KCC therefore reveals how the reform has altered expectations regarding teachers' interpretation and use of curriculum materials.

The Interrelated Nature of the MKT Domains

Although the six MKT domains are described separately, teaching tasks rarely draw on only one form of knowledge. Consider a teacher responding to an incorrect student solution. The teacher must understand the mathematics involved through CCK, analyze the mathematical structure of the error through SCK, recognize whether the error reflects a common misconception through KCS, decide how to respond instructionally through KCT, connect the idea to related topics through HCK, and ensure that the response is appropriate to the curriculum level through KCC.

The overlap among the domains creates methodological challenges when using MKT as an analytic framework. A curriculum excerpt may reasonably reflect more than one domain, and the domain represented may depend on what the statement expects the teacher to know or do. For this reason, the present study does not treat the categories as rigid or mutually exclusive. Instead, they are used as analytic lenses for identifying the different forms of knowledge implied by the objectives, learning outcomes, activities, pedagogical exemplars, and assessment guidance in the two curricula.

The MKT framework is especially appropriate for comparing Ghana's Objective-Based and Standards-Based SHS mathematics curricula because it directs attention beyond differences in mathematical topics. It makes it possible to examine whether the curricula emphasize procedural competence, mathematical explanation, student thinking, instructional decision-making, curricular progression, or connections across mathematical ideas. In this way, the framework provides a systematic basis for determining how curriculum reform has reshaped the knowledge demands placed on mathematics teachers.

Empirical Studies on Mathematical Knowledge for Teaching

Since the development of the Mathematical Knowledge for Teaching (MKT) framework, numerous studies have examined its relationship with effective mathematics instruction, teacher preparation, and student learning outcomes. These studies consistently demonstrate that effective mathematics teaching requires more than strong disciplinary knowledge; it depends on teachers' ability to interpret mathematical ideas, anticipate students' thinking, make informed instructional decisions, and connect mathematical concepts across different contexts. Consequently, MKT has become one of the most widely used theoretical frameworks for understanding the knowledge required for teaching mathematics.

One of the earliest large-scale investigations into MKT was conducted by Hill, Rowan, and Ball (2005), who examined the relationship between teachers' mathematical knowledge for teaching and students' achievement in elementary mathematics. Their findings indicated that teachers with stronger MKT contributed to significantly greater gains in student learning than teachers whose knowledge was comparatively weaker. The study provided empirical evidence that teacher knowledge influences not only instructional quality but also students' mathematical achievement, thereby establishing MKT as an important predictor of effective mathematics teaching.

Subsequent research has expanded understanding of how MKT influences classroom practice. Hill, Ball, and Schilling (2008) argued that teachers draw simultaneously on multiple domains of MKT during instruction rather than relying on isolated forms of knowledge. They demonstrated that activities such as interpreting students' responses, selecting examples, sequencing mathematical ideas, and choosing appropriate representations require the integration of content knowledge with pedagogical decision-making. Their work further emphasized that the six MKT domains should not be viewed as independent categories but as interconnected forms of professional knowledge that support effective mathematics instruction.

Research has also examined the application of MKT in different educational contexts. Cole (2011), for example, explored the relationship between teachers' mathematical knowledge and instructional practice, concluding that teachers require specialized mathematical understanding that extends beyond university-level mathematics. Similarly, Nsiah-Asante and Mereku (2012) highlighted the importance of strengthening Ghanaian mathematics teachers' professional knowledge to improve classroom instruction and student learning. Their work emphasized that teacher effectiveness depends not only on knowledge of mathematical content but also on the ability to communicate mathematical ideas, diagnose misconceptions, and select instructional strategies appropriate for diverse learners.

More recent studies have continued to demonstrate the usefulness of the MKT framework for examining mathematics teaching. Narh-Kert (2020), for instance, employed the framework to investigate teachers' mathematical knowledge within Ghanaian schools and found that differences in teachers' instructional decisions could be understood through variations in the MKT domains they demonstrated. Similarly, Wagner et al. (2007) argued that curriculum documents, instructional resources, and classroom practice collectively shape the opportunities teachers have to develop and apply Mathematical Knowledge for Teaching. These studies reinforce the view that MKT is not only an individual characteristic of teachers but also a framework through which curriculum expectations can be examined.

Although the empirical literature has established the importance of Mathematical Knowledge for Teaching in improving instruction and student learning, most existing studies focus on teachers themselves. Researchers have typically measured teachers' MKT, investigated its relationship with classroom practice, evaluated professional development programmes, or examined its influence on students' achievement. Comparatively few studies have used the MKT framework to analyse curriculum documents and investigate how curriculum reform reshapes the knowledge demands placed on teachers.

This distinction is particularly important within the Ghanaian context. Existing studies on Ghana's Standards-Based Curriculum have concentrated largely on teachers' perceptions of the reform, implementation challenges, and learner-centred pedagogies. At the same time, studies employing the MKT framework have focused primarily on teachers' instructional knowledge and classroom practice. These two strands of research have largely developed independently. Consequently, little is known about how Ghana's curriculum reform itself has altered the forms of Mathematical Knowledge for Teaching embedded within the curriculum or the knowledge expectations placed on teachers.

The present study addresses this gap by applying the MKT framework directly to Ghana's Objective-Based and Standards-Based Senior High School mathematics curricula. Rather than evaluating teachers' knowledge or examining classroom implementation, the study investigates how the curriculum documents themselves communicate expectations regarding teachers' mathematical and pedagogical knowledge. By comparing the two curricula systematically, the study contributes to both the curriculum reform literature and the growing body of research on Mathematical Knowledge for Teaching.

Summary of Literature and Research Gap

The literature reviewed demonstrates that mathematics curriculum reform has evolved from an emphasis on content coverage and procedural competence to approaches that promote conceptual understanding, problem solving, learner-centred pedagogy, and the development of twenty-first-century competencies. International evidence further suggests that the success of curriculum reform depends not only on the quality of curriculum design but also on teachers' capacity to interpret and implement new instructional expectations effectively. Similarly, studies conducted in Ghana indicate that while teachers generally support the philosophy underpinning the Standards-Based Curriculum, they continue to encounter challenges related to professional preparation, instructional resources, and the implementation of learner-centred pedagogies.

The review also highlights the significant contribution of the Mathematical Knowledge for Teaching (MKT) framework to understanding effective mathematics teaching. Previous studies have established that teachers require specialized forms of mathematical and pedagogical knowledge beyond disciplinary content knowledge alone and that these forms of knowledge influence instructional quality and student learning. Consequently, MKT has become one of the most influential frameworks for examining the knowledge required for effective mathematics instruction.

Despite these contributions, two important observations emerge from the literature. First, studies on curriculum reform have focused predominantly on curriculum implementation, teachers' perceptions, instructional practices, and the challenges associated with educational change. Second, research employing the MKT framework has concentrated largely on assessing teachers' knowledge, professional development, and classroom practice. These two bodies of literature have developed largely independently, with limited attention given to the relationship between curriculum reform and the mathematical knowledge expected of teachers.

More specifically, the literature reviewed for this study did not identify a systematic examination of Ghana's transition from the 2010 Objective-Based Senior High School Mathematics Curriculum to the 2023 Standards-Based Senior High School Mathematics Curriculum through the framework of Mathematical Knowledge for Teaching. As a result, there remains limited understanding of how curriculum reform has reshaped the knowledge demands placed on mathematics teachers and the implications of those changes for teacher preparation and professional development.

This study addresses that gap by applying the Mathematical Knowledge for Teaching framework to a comparative qualitative document analysis of the Objective-Based and Standards-Based Senior High School mathematics curricula in Ghana. Rather than evaluating teachers' classroom practices or measuring student achievement, the study investigates how the curriculum documents themselves represent the mathematical and pedagogical knowledge required for effective teaching. In doing so, it contributes to the growing literature on curriculum reform by demonstrating how the MKT framework can be used to examine changes in curriculum expectations and to provide evidence that can inform curriculum development, teacher education, and future mathematics education reforms.

METHODOLOGY

Research Design

This study employed a qualitative document analysis design to compare Ghana's 2010 Objective-Based Senior High School Mathematics Curriculum and the 2023 Standards-Based Senior High School Mathematics Curriculum through the framework of Mathematical Knowledge for Teaching (MKT). Qualitative document analysis is an appropriate research approach for examining the meanings, assumptions, and educational expectations embedded within written documents. Unlike quantitative approaches that focus on numerical measurement, qualitative document analysis enables researchers to interpret how ideas are represented, organized, and communicated within official texts (Bowen, 2009).

Curriculum documents are more than instructional guides; they communicate educational philosophies, learning priorities, pedagogical expectations, and assumptions about the knowledge teachers require to support student learning. Consequently, they provide an appropriate source for investigating how curriculum reform reshapes expectations for mathematics teaching. Since the purpose of this study was to examine changes in the Mathematical Knowledge for Teaching embedded within two curriculum documents rather than to evaluate classroom implementation or teacher effectiveness, qualitative document analysis provided a suitable methodological approach.

The study adopted a comparative research design in which the two curriculum documents were analyzed systematically using the six domains of the Mathematical Knowledge for Teaching framework as analytical categories. This approach made it possible to identify similarities and differences between the curricula and to examine how the transition from the Objective-Based Curriculum to the Standards-Based Curriculum altered the mathematical and pedagogical knowledge expected of teachers.

Data Sources

The data for this study consisted of two official curriculum documents developed by the Ministry of Education of Ghana for Senior High School Mathematics. These documents represent two successive phases of curriculum reform in Ghana and provide the basis for examining changes in the mathematical and pedagogical knowledge expected of mathematics teachers.

The first document was the Teaching Syllabus for Senior High School Core Mathematics, published in 2010 by the Curriculum Research and Development Division of the Ghana Education Service (Ministry of Education, 2010). This curriculum, referred to in the present study as the 2010 Objective-Based Curriculum (OBC), organized instruction around specific behavioural objectives, content, teaching and learning activities, and evaluation. It served as the official mathematics curriculum for Senior High Schools until the introduction of the Standards-Based Curriculum.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

The second document was the Mathematics Curriculum for Secondary Education (Senior High School 1–3), published by the National Council for Curriculum and Assessment (NaCCA, 2023). This document, referred to as the 2023 Standards-Based Curriculum (SBC), is the current curriculum guiding mathematics instruction in Ghanaian Senior High Schools. Unlike the OBC, it is organized around strands, sub-strands, content standards, learning outcomes, learning indicators, pedagogical exemplars, and assessment strategies, reflecting Ghana's transition toward competency-based education.

These two curriculum documents were purposively selected because they represent the official curriculum immediately before and after Ghana's most recent Senior High School mathematics curriculum reform. Their sequential nature makes them appropriate for comparative analysis, allowing changes in curriculum philosophy, instructional expectations, and teacher knowledge demands to be examined systematically.

The curriculum documents were treated as primary data sources because they explicitly communicate the intended goals of mathematics education, the organization of mathematical content, recommended pedagogical approaches, expected learning outcomes, assessment practices, and guidance provided to teachers. Since the purpose of this study was to investigate how curriculum reform has reshaped the Mathematical Knowledge for Teaching embedded within curriculum documents, these official policy documents provided the most appropriate and authoritative source of data.

In addition to the two curriculum documents, the 2023, 2024, and 2025 Chief Examiners' reports for Core Mathematics were reviewed as supplementary contextual documents. These reports were not included in the MKT coding or frequency analysis. They were used only to provide baseline evidence of recurring areas of student strength and difficulty under the Objective-Based Curriculum and to support the discussion of implications for curriculum implementation, teacher knowledge, and teacher preparation.

Analytical Framework

This study was guided by the Mathematical Knowledge for Teaching (MKT) framework developed by Ball, Thames, and Phelps (2008). The framework was selected because it provides a comprehensive theoretical lens for examining the mathematical and pedagogical knowledge required for effective mathematics teaching. Unlike frameworks that focus primarily on curriculum content or instructional methods, MKT enables the analysis of the different forms of knowledge that curriculum documents implicitly and explicitly expect teachers to possess.

The MKT framework comprises six interconnected domains: Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), Horizon Content Knowledge (HCK), Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT), and Knowledge of Content and Curriculum (KCC). Together, these domains capture both the mathematical understanding and pedagogical expertise required to support meaningful mathematics learning.

Within this study, the six MKT domains served as deductive coding categories for analysing the two curriculum documents. Each curriculum statement within the selected analytical sections—including specific objectives, content standards, learning outcomes, pedagogical guidance, teaching and learning activities, assessment recommendations, and curriculum notes—was examined to determine the form or forms of Mathematical Knowledge for Teaching that it represented. Coding decisions were guided by the conceptual definitions of the six MKT domains established by Ball et al. (2008) and informed by subsequent studies applying the framework to mathematics education research.

Because curriculum statements frequently reflected more than one aspect of teacher knowledge, coding was not restricted to mutually exclusive categories. Where appropriate, a curriculum statement was assigned to multiple MKT domains when the evidence demonstrated that it simultaneously represented different forms of mathematical and pedagogical knowledge. This approach acknowledges the integrated nature of teaching, where teachers routinely draw upon multiple knowledge domains while planning, delivering, and evaluating instruction.

The use of the MKT framework enabled the analysis to move beyond identifying differences in curriculum content. Instead, it provided a systematic basis for examining how Ghana's curriculum reform has altered the professional knowledge expected of mathematics teachers and how those expectations are reflected within the official curriculum documents.

The curriculum documents were coded by the researcher using ATLAS.ti qualitative data analysis software. The coding process was conducted under academic supervision, with coding decisions and interpretations discussed during supervisory meetings to support consistent application of the operational definitions. Each curriculum statement was treated as a coding unit, and a statement could receive more than one MKT code where it reflected multiple forms of teacher knowledge. Each assigned code was counted as one coded instance; consequently, the reported frequencies represent the number of MKT codes identified rather than the number of unique curriculum statements. Since the coding was undertaken by one researcher, intercoder reliability was not calculated.

Table 1. Operational Coding Framework for Mathematical Knowledge for Teaching

MKT Domain	**Operational Definition in this Study**	**Examples of Curriculum Indicators**
Common Content Knowledge (CCK)	Mathematical knowledge required to correctly solve, apply, or demonstrate mathematical procedures expected in the curriculum.	"Solve problems that involve SI and imperial units in surface area measurements and verify the solutions…"
Specialized Content Knowledge (SCK)	Mathematical knowledge unique to teaching that enables teachers to explain concepts, justify procedures, analyse solutions, and represent mathematics in multiple ways.	"Investigate the three basic trigonometric ratios…", followed by "Using ideas from Pythagoras' theorem, deduce the basic six ratios in trigonometry." This requires teachers to explain conceptual relationships rather than only procedures.
Horizon Content Knowledge (HCK)	Knowledge of relationships among mathematical topics across strands, grade levels, and future learning.	Learners are asked to "draw on their experiences in nets, area, perimeter, etc., to discuss how the various formulae can be generated,…"
Knowledge of Content and Students (KCS)	Knowledge of how students learn mathematics, including their prior knowledge, misconceptions, and likely responses.	"Recall learners' familiarity with Pythagoras' theorem," "Review learners' basic knowledge of congruence and similarity," and extensive emphasis on differentiated instruction and Universal Design for Learning.
Knowledge of Content and Teaching (KCT)	Knowledge required to organize and deliver mathematics instruction effectively.	Frequent instructional directives such as "Guide students…", "Assist students…", "Discuss with students…", "Encourage students…", and "Pose word problems…".

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

Knowledge of Content and Curriculum (KCC)	Knowledge of curriculum structure, learning progressions, standards, and assessment expectations.	Curriculum organised into Strands → Sub-strands → Content Standards → Learning Indicators → Pedagogical Exemplars → Assessment, with explicit learning progressions and competency expectations.

Source: Adapted from Ball, Thames, and Phelps (2008).

The examples presented in Table 1 are illustrative rather than exhaustive. During analysis, curriculum statements were not restricted to a single MKT domain. Where a statement simultaneously reflected multiple forms of teacher knowledge, multiple codes were assigned. For example, a learning activity requiring teachers to explain a mathematical concept, connect it to learners' prior knowledge, and select an appropriate instructional strategy was coded as Specialized Content Knowledge (SCK), Knowledge of Content and Students (KCS), and Knowledge of Content and Teaching (KCT), respectively. This approach reflects the integrated nature of Mathematical Knowledge for Teaching proposed by Ball et al. (2008).

RESULTS

The findings presented in this section are based on a comparative qualitative document analysis of the 2010 Objective-Based Senior High School Mathematics Curriculum (OBC) and the 2023 Standards-Based Senior High School Mathematics Curriculum (SBC) using the Mathematical Knowledge for Teaching (MKT) framework developed by Ball et al. (2008). Because the two curriculum documents differ considerably in structure, format, and organization, the analysis focused on curriculum components that explicitly communicate expectations for mathematics teaching and learning rather than coding every section of each document.

For the OBC, the analysis focused on the units, specific objectives, content, teaching and learning activities, and evaluation sections. For the SBC, coding focused on the content standards, learning outcomes, learning indicators, pedagogical exemplars, twenty-first-century skills and competencies, Gender Equality and Social Inclusion (GESI), and assessment guidance. These sections were selected because they most directly communicate the mathematical content to be taught, the pedagogical approaches recommended, and the forms of teacher knowledge required to enact the curriculum effectively.

The curriculum documents were analysed deductively using the six domains of Mathematical Knowledge for Teaching: Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), Horizon Content Knowledge (HCK), Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT), and Knowledge of Content and Curriculum (KCC). Where a curriculum statement reflected more than one domain, multiple codes were assigned in accordance with the coding protocol described in the Methodology.

Overall Distribution of Mathematical Knowledge for Teaching Domains

Table 2 presents the distribution of the six Mathematical Knowledge for Teaching domains identified across the two curriculum documents. A total of 3,249 coded instances were recorded, comprising 1,102 instances from the 2010 OBC and 2,147 instances from the 2023 SBC. The larger number of coded instances in the SBC should be interpreted in relation to its broader scope, greater pedagogical detail, different organizational structure, and larger volume of analysable curriculum statements. The frequencies therefore provide a descriptive indication of the visibility of the MKT domains within each document rather than a direct measure of curriculum quality.

Table 2. Frequency Distribution of MKT Domains Identified in the 2010 OBC and 2023 SBC

MKT domains	2010 OBC, n	2010 OBC, %	2023 SBC, n	2023 SBC, %	Total, n
Common Content Knowledge	41	3.7	151	7.0	192

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Specialized Content Knowledge	740	67.2	953	44.4	1,693
Horizon Content Knowledge	0	0.0	113	5.3	113
Knowledge of Content and Students	0	0.0	11	0.5	11
Knowledge of Content and Teaching	262	23.8	895	41.7	1,157
Knowledge of Content and Curriculum	59	5.4	24	1.1	83
Total coded instances	1,102	100.0	2,147	100.0	3,249

Note. Percentages were calculated using the total number of coded instances within each curriculum. Because a curriculum statement could receive more than one MKT code, the frequencies represent coded instances rather than unique curriculum statements. Minor differences in totals may occur because of rounding.

Before presenting the findings in detail, it is important to clarify the interpretation of the absence of Horizon Content Knowledge (HCK) and Knowledge of Content and Students (KCS) within the 2010 OBC. In this study, the absence of these codes does not imply that teachers working within the OBC were unable to draw upon these forms of knowledge during classroom instruction. Rather, it indicates that the written curriculum did not contain statements that explicitly satisfied the operational definitions established for HCK and KCS. Consequently, the findings describe the visibility of Mathematical Knowledge for Teaching within the curriculum documents rather than the knowledge teachers may demonstrate in practice.

Similarly, curriculum statements were coded as HCK only when they explicitly connected mathematical ideas across topics, strands, or stages of learning. General references to completing a unit or teaching a topic were not considered evidence of Horizon Content Knowledge unless they clearly established broader mathematical relationships. Likewise, KCS was assigned only when curriculum statements explicitly referred to learners' prior knowledge, likely misconceptions, conceptual difficulties, or anticipated patterns of mathematical thinking. General instructional directives, even when learner-centred, were not coded as KCS unless they specifically addressed students' mathematical understanding.

The coding results reveal clear differences in both the frequency and proportional distribution of the six MKT domains across the two curricula. Specialized Content Knowledge recorded the highest number of coded instances overall, with 1,693 codes, followed by Knowledge of Content and Teaching with 1,157 codes. Common Content Knowledge appeared 192 times, while Knowledge of Content and Curriculum appeared 83 times. Horizon Content Knowledge and Knowledge of Content and Students were less frequently represented, with 113 and 11 coded instances, respectively.

Comparison of the two curriculum documents revealed important changes in the relative visibility of the MKT domains. In the OBC, Specialized Content Knowledge accounted for 67.2% of all coded instances, followed by Knowledge of Content and Teaching at 23.8%. In the SBC, Specialized Content Knowledge remained the largest domain but declined proportionally to 44.4%, while Knowledge of Content and Teaching increased substantially to 41.7%. Common Content Knowledge also increased from 3.7% of the OBC codes to 7.0% of the SBC codes. Horizon Content Knowledge and Knowledge of Content and Students were identified only in the SBC, accounting for 5.3% and 0.5% of its coded instances, respectively. These findings indicate that the SBC distributes its teacher-knowledge expectations across a broader range of mathematical and pedagogical domains than the OBC.

Knowledge of Content and Curriculum was the only domain that declined in both frequency and proportional representation, decreasing from 59 coded instances, or 5.4% of the OBC codes, to 24 instances, or 1.1% of the

SBC codes. This finding should not necessarily be interpreted as evidence that curriculum knowledge has become less important. Rather, it may reflect differences in the organization and presentation of the two documents. The OBC divides mathematical content into numerous units and sub-units, producing repeated references to curriculum organization. The SBC, by contrast, integrates curriculum expectations within broader strands, content standards, learning outcomes, pedagogical exemplars, and assessment guidance. The lower number of explicit KCC codes may therefore result partly from the way curriculum information is structured and communicated.

The overall coding pattern indicates that both curricula emphasize teachers' mathematical knowledge and instructional practice. However, the distribution of codes suggests that the 2023 Standards-Based Curriculum makes a wider range of Mathematical Knowledge for Teaching explicit within the curriculum document than the 2010 Objective-Based Curriculum. The following sections examine these differences in greater detail by analysing each MKT domain individually.

Curriculum Reform Increased the Relative Visibility of Pedagogical Content Knowledge

To provide a broader perspective on the findings, the coded instances were first examined using Ball et al.'s (2008) classification of Mathematical Knowledge for Teaching into Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). Subject Matter Knowledge comprises Common Content Knowledge (CCK), Specialized Content Knowledge (SCK), and Horizon Content Knowledge (HCK), whereas Pedagogical Content Knowledge comprises Knowledge of Content and Students (KCS), Knowledge of Content and Teaching (KCT), and Knowledge of Content and Curriculum (KCC).

As shown in Table 3, Subject Matter Knowledge accounted for 781 coded instances in the OBC and 1,217 coded instances in the SBC. Pedagogical Content Knowledge accounted for 321 coded instances in the OBC and 930 coded instances in the SBC. Although both categories increased in frequency, the proportional distribution reveals a more important shift. Subject Matter Knowledge represented 70.9% of the coded instances in the OBC but 56.7% in the SBC. In contrast, Pedagogical Content Knowledge increased from 29.1% of the OBC codes to 43.3% of the SBC codes.

Table 3. Distribution of Subject Matter Knowledge and Pedagogical Content Knowledge

Knowledge Category	**2010 OBC, n**	**2010 OBC, %**	**2023 SBC, n**	**2023 SBC, %**
Subject Matter Knowledge	781	70.9	1,217	56.7
Pedagogical Content Knowledge	321	29.1	930	43.3
Total coded instances	1,102	100.0	2,147	100.0

Note. Subject Matter Knowledge comprises Common Content Knowledge, Specialized Content Knowledge, and Horizon Content Knowledge. Pedagogical Content Knowledge comprises Knowledge of Content and Students, Knowledge of Content and Teaching, and Knowledge of Content and Curriculum.

These results indicate that the OBC was more strongly weighted toward Subject Matter Knowledge, whereas the SBC presents a more balanced distribution between Subject Matter Knowledge and Pedagogical Content Knowledge. Subject Matter Knowledge remains the larger category in both curricula, but the considerably higher proportion of Pedagogical Content Knowledge in the SBC suggests that the reform makes teaching-related knowledge more visible. In particular, the SBC gives greater attention to instructional organization, learner participation, pedagogical exemplars, assessment practices, inclusive teaching, and the development of competencies.

This shift does not suggest that mathematical content knowledge has become less important. Rather, it indicates that the SBC places mathematical knowledge within a broader pedagogical framework. Teachers are expected not only to understand the mathematics being taught but also to select appropriate representations, organize inquiry and discussion, respond to learners' needs, connect content to practical situations, and align instruction with curriculum standards and assessment expectations.

The Standards-Based Curriculum Expands the Knowledge Expected of Mathematics Teachers

Beyond the increase in the overall frequency of Mathematical Knowledge for Teaching (MKT) domains, the comparative analysis revealed a substantive change in the nature of the knowledge expected of mathematics teachers. While both curricula require teachers to possess strong mathematical knowledge, the 2023 Standards-Based Curriculum (SBC) extends these expectations beyond procedural competence to include conceptual understanding, mathematical reasoning, learner-centred pedagogy, and the development of twenty-first-century competencies.

The analysis showed that the most substantial increases occurred in Specialized Content Knowledge (SCK) and Knowledge of Content and Teaching (KCT). Compared with the 2010 Objective-Based Curriculum (OBC), the SBC places considerably greater emphasis on teachers' ability to explain mathematical concepts, facilitate inquiry, encourage multiple solution strategies, and support learners in constructing mathematical understanding. Rather than presenting mathematics primarily as a sequence of procedures to be mastered, the SBC encourages teachers to create opportunities for investigation, discussion, collaboration, and problem solving.

A notable finding is the explicit appearance of Horizon Content Knowledge (HCK) and Knowledge of Content and Students (KCS) within the SBC. Under the coding framework adopted in this study, these domains were not explicitly represented in the OBC but appeared repeatedly throughout the SBC. The curriculum encourages teachers to connect mathematical ideas across strands, relate new concepts to learners' prior knowledge, and consider diverse learner needs through differentiated instruction and inclusive pedagogical practices. These features indicate a broader conception of mathematics teaching in which teachers are expected not only to possess mathematical knowledge but also to understand how mathematical ideas develop and how students engage with them.

Illustrative curriculum statements provide further evidence of this change. For example, the SBC asks learners to "draw on their experiences in nets, area, perimeter, etc., to discuss how the various formulae can be generated." This statement was coded as Horizon Content Knowledge because it explicitly connects learners' previous mathematical experiences with the development of new ideas. Similarly, directives such as "recall learners' familiarity with Pythagoras' theorem" and "review learners' basic knowledge of congruence and similarity" were coded as Knowledge of Content and Students because they require teachers to consider learners' prior mathematical knowledge when planning instruction. In contrast, the OBC more frequently uses directives such as "guide students," "assist students," "review with students," and "discuss with students." These statements mainly reflect Knowledge of Content and Teaching because they specify how teachers should organize and support instruction, but they do not explicitly identify learners' prior conceptions, misconceptions, or likely mathematical responses.

Table 4 provides an interpretive summary of the principal differences observed between the two curricula based on the coding patterns and qualitative analysis of the curriculum documents.

Table 4. Major Changes in the Mathematical Knowledge Expected of Teachers

Aspect of Teacher Knowledge	**2010 OBC**	**2023 SBC**
Mathematical procedures	Strong emphasis	Strong emphasis
Conceptual understanding	Moderate emphasis	Strong emphasis
Mathematical reasoning	Limited emphasis	Strong emphasis
Multiple representations	Limited	Explicitly encouraged

Inquiry-based learning	Limited	Extensive
Collaborative learning	Limited	Extensive
Connections across mathematical ideas	Implicit	Explicit
Attention to learners' prior knowledge	Rare	Frequent
Inclusive and differentiated instruction	Not explicit	Explicit
Twenty-first-century competencies	Not explicit	Embedded throughout

Note. The descriptors used in this table are interpretive summaries of the qualitative coding patterns and curriculum language. They do not represent scores derived from a standardized measurement scale.

Overall, the findings indicate that the curriculum reform extends the expectations placed on mathematics teachers beyond mathematical proficiency alone. The SBC presents mathematics teaching as a professional activity requiring teachers to integrate mathematical understanding, pedagogical decision-making, knowledge of learners, and curriculum interpretation in ways that are less visible within the OBC.

Curriculum Organization Influences the Visibility of Mathematical Knowledge for Teaching

An important methodological finding emerging from this study concerns the influence of curriculum organization on the visibility of Mathematical Knowledge for Teaching. Although the analysis focused on the knowledge embedded within the curriculum documents, differences in the structure of the two curricula affected how particular MKT domains were represented.

The OBC is organized around units, specific objectives, content, teaching and learning activities, and evaluation. This structure provides repeated references to curriculum organization and instructional sequencing, resulting in relatively frequent coding of Knowledge of Content and Curriculum (KCC). In contrast, the SBC adopts a broader organizational structure comprising strands, sub-strands, content standards, learning outcomes, learning indicators, pedagogical exemplars, assessment strategies, and core competencies. Rather than repeatedly specifying curriculum organization, many of these elements are integrated within broader instructional guidance.

Consequently, although the SBC contains fewer explicit instances coded as KCC, this finding should not be interpreted as indicating that curriculum knowledge has become less important. Instead, it reflects the different ways in which curriculum information is communicated. In the OBC, curriculum organization is presented through repeated structural components, whereas in the SBC, curriculum expectations are embedded within integrated standards, learning progressions, and pedagogical guidance.

This observation illustrates an important consideration for qualitative curriculum analysis. The frequency with which a particular MKT domain appears is influenced not only by the educational philosophy of the curriculum but also by the manner in which curriculum information is organized and presented. Consequently, coding frequencies should be interpreted alongside the qualitative characteristics of the curriculum documents rather than viewed as direct measures of emphasis.

Taken together, the findings show clear differences in the range and distribution of Mathematical Knowledge for Teaching represented in the two curriculum documents. The implications of these differences for curriculum reform, teacher education, and professional development are discussed in the next section.

DISCUSSION

Curriculum Reform Redefines Mathematical Knowledge for Teaching

The findings of this study suggest that Ghana's transition from the 2010 Objective-Based Curriculum (OBC) to the 2023 Standards-Based Curriculum (SBC) represents more than a revision of curriculum content or instructional organization. Rather, it reflects a fundamental reconceptualization of the mathematical knowledge expected of Senior High School mathematics teachers. Through the lens of the Mathematical Knowledge for Teaching (MKT) framework, the analysis demonstrates that curriculum reform has broadened expectations beyond procedural competence to include conceptual understanding, mathematical reasoning, learner-centred pedagogy, curriculum interpretation, and responsiveness to students' learning.

One of the most significant findings was the shift in the balance between Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). While both curricula strongly emphasize teachers' mathematical knowledge, the Standards-Based Curriculum substantially increases the visibility of pedagogical knowledge by incorporating learning outcomes, pedagogical exemplars, assessment guidance, and core competencies throughout the curriculum. This finding supports Ball, Thames, and Phelps' (2008) argument that effective mathematics teaching depends not only on knowing mathematics but also on knowing how mathematical ideas should be represented, sequenced, and communicated to learners.

The analysis further revealed that the Standards-Based Curriculum expands teachers' professional responsibilities beyond delivering mathematical content. Teachers are now expected to facilitate inquiry, encourage collaboration, support mathematical communication, integrate technology, promote critical thinking, and respond to learners' diverse needs. These expectations require teachers to draw simultaneously on multiple domains of Mathematical Knowledge for Teaching rather than relying primarily on procedural content knowledge. Consequently, the curriculum positions teachers as facilitators of mathematical understanding rather than transmitters of mathematical procedures.

The emergence of explicit Horizon Content Knowledge (HCK) and Knowledge of Content and Students (KCS) within the Standards-Based Curriculum further illustrates this shift. The curriculum encourages teachers to connect mathematical ideas across topics, activate learners' prior knowledge, accommodate learner diversity, and support inclusive participation in mathematics classrooms. Although experienced teachers working under the Objective-Based Curriculum may also have demonstrated these forms of knowledge, the findings indicate that such expectations were not explicitly communicated within the written curriculum. The Standards-Based Curriculum therefore makes previously implicit expectations visible, providing clearer guidance regarding the professional knowledge required for effective mathematics teaching.

Taken together, these findings suggest that curriculum reform should not be understood solely as a change in what students are expected to learn. Equally important is the way curriculum reform reshapes what teachers are expected to know. By examining curriculum reform through the framework of Mathematical Knowledge for Teaching, this study demonstrates that changes in curriculum philosophy are accompanied by corresponding changes in teacher knowledge expectations.

Implications for Mathematics Teacher Education and Professional Development

The findings have important implications for mathematics teacher education in Ghana. Curriculum reforms can only achieve their intended outcomes when teachers possess the knowledge and skills required to interpret and implement the new curriculum effectively. The broader expectations identified within the Standards-Based Curriculum suggest that teacher preparation programmes must move beyond strengthening mathematical content knowledge alone to developing teachers' Mathematical Knowledge for Teaching in all its dimensions.

This implication is consistent with previous studies conducted in Ghana. Aboagye and Yawson (2020) found that although teachers generally supported the philosophy of the Standards-Based Curriculum, many reported inadequate preparation, insufficient teaching resources, and limited involvement during curriculum development. Similarly, Addai-Mununkum and Setordzi (2023) observed that teachers appreciated learner-

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VIII August 2026

centred approaches but experienced considerable difficulty implementing them consistently because of limited professional development and instructional support. The findings of the present study help explain these challenges by demonstrating that the curriculum itself requires broader and more integrated forms of teacher knowledge than its predecessor.

Teacher education institutions therefore need to reconsider how prospective mathematics teachers are prepared. Pre-service programmes should provide opportunities for future teachers to develop conceptual understanding alongside pedagogical reasoning, curriculum interpretation, assessment literacy, and knowledge of students' mathematical thinking. Similarly, in-service professional development should focus not only on familiarizing teachers with curriculum documents but also on strengthening their ability to implement inquiry-based instruction, facilitate mathematical discussion, anticipate misconceptions, and connect mathematical ideas across topics.

The findings also have implications for curriculum developers and educational policymakers. The Standards-Based Curriculum communicates ambitious expectations regarding mathematics teaching. However, the successful realization of these expectations depends upon sustained investment in teacher preparation, professional learning, instructional resources, and ongoing curriculum support. Curriculum reform should therefore be viewed as a comprehensive process involving curriculum design, teacher development, assessment reform, and classroom implementation rather than the publication of a new curriculum document alone.

Curriculum Reform in Context: Insights from the Chief Examiners' Reports

In addition to the curriculum analysis presented in this study, the Chief Examiners' reports for 2023, 2024, and 2025 provide useful baseline evidence of students' mathematics performance under the objective-based senior high school curriculum. Since the first cohort taught under the standards-based curriculum has not yet taken the West African Senior School Certificate Examination, which is expected in 2027, the reports cannot presently be used to compare student outcomes across the two curricula. Nevertheless, they provide useful contextual evidence of persistent areas of difficulty under the previous curriculum and may offer insights into curriculum implementation, teacher knowledge, and teacher preparation.

Across the three reporting years, students' overall performance was generally described as satisfactory or encouraging, with some improvements observed. Students demonstrated relative strength in procedural and topic-specific areas such as probability, bearings, trigonometry, vectors, transformations, and basic statistical concepts such as the calculation of the mean. These strengths suggest that students were more comfortable with familiar and structured tasks requiring the direct application of previously learned procedures.

However, the weaknesses identified across the reports were notably persistent. Students experienced difficulties representing mathematical information diagrammatically, translating between verbal, symbolic, and visual forms, and solving global or real-life mathematical problems. Other recurring difficulties included logical reasoning, plane geometry, mensuration, business mathematics, cumulative frequency, and translating word problems into mathematical expressions. These patterns suggest that many students possessed procedural knowledge but lacked the flexible, connected, and conceptual understanding required to interpret, represent, and apply mathematics in unfamiliar contexts.

From the perspective of Mathematical Knowledge for Teaching, these weaknesses have important implications. Difficulties in mathematical representation, interpretation, and application may indicate that classroom instruction has emphasized procedural fluency without sufficient attention to conceptual understanding and connections among representations. Addressing these challenges requires more than teachers' Common Content Knowledge. Teachers also need Specialized Content Knowledge to unpack mathematical concepts, provide alternative explanations, and move effectively among verbal, symbolic, graphical, and diagrammatic representations. They further require Knowledge of Content and Students to anticipate misconceptions and recognize the difficulties students are likely to encounter in word problems, diagrams, and contextual applications, as well as Knowledge of Content and Teaching to select appropriate examples, representations, and instructional sequences.

The recommendations provided in the Chief Examiners' reports further emphasize the role of the teacher. Suggestions such as giving students additional practice, guiding them through problem-solving processes, encouraging independent work, and organizing refresher courses for teachers in areas such as geometry and trigonometry indicate that improvements in student outcomes depend substantially on teachers' instructional capacity. Although the Objective-Based Curriculum contained considerable emphasis on aspects of SCK, the recurring weaknesses reported in students' WASSCE performance suggest that the curriculum's intended outcomes were not fully realized. The presence of particular knowledge demands in a curriculum document does not, by itself, demonstrate that those demands were consistently enacted in classroom instruction. One possible explanation is that some teachers may have required additional preparation and support to interpret and implement these expectations effectively. The present study does not provide direct evidence about teachers' classroom knowledge or establish the causes of students' performance patterns. Nevertheless, this interpretation is consistent with Hill et al. (2005), who found a positive association between teachers' MKT and students' mathematics achievement. This concern is especially significant because the objective-based curriculum introduced in 2010 explicitly aimed to enable students to "organize, interpret and present information accurately in written, graphical and diagrammatic forms" and to "develop the ability to translate word problems (story problems) into mathematical language and solve them with related mathematical knowledge" (MOE, 2010, p. iii). Yet, fifteen years after its introduction, the Chief Examiners' reports continued to identify weaknesses in these same areas. This suggests that some of the curriculum's central intentions were not fully realized in classroom practice. The problem, therefore, may not lie solely in the curriculum document, but also in the extent to which teachers were prepared to translate its expectations into meaningful learning experiences.

The reports also reveal a limitation in how improvement is framed. Although they appropriately identify areas of student weakness and recommend instructional remedies, they do not explicitly address the forms of teacher knowledge required to implement those recommendations. Encouraging better problem solving, representation, and real-life application presupposes that teachers can interpret mathematical ideas flexibly, connect multiple representations, select productive instructional approaches, and diagnose student misconceptions. Without adequately developed SCK, KCS, and KCT, such recommendations may be difficult to enact effectively.

Accordingly, the Chief Examiners' reports provide useful baseline evidence of recurring strengths and weaknesses in students' mathematics performance under the Objective-Based Curriculum. These patterns help contextualize the competencies emphasized in the Standards-Based Curriculum, particularly critical thinking, problem solving, communication, conceptual understanding, and the application of mathematics in real-life contexts. However, the findings of this study suggest that the success of the reform will depend not only on the design of the new curriculum but also on whether teachers are equipped with the forms of MKT necessary to enact it. Curriculum reform alone may therefore be insufficient to improve student outcomes. Equal attention must be given to teacher preparation and professional development, particularly in conceptual understanding, multiple representations, instructional decision-making, and responsiveness to student thinking. Without such support, the patterns of performance observed under the objective-based curriculum may persist under the standards-based curriculum.

LIMITATIONS

The findings of this study should be interpreted in light of several limitations. First, the curriculum documents were not coded in their entirety; instead, the analysis focused on sections that most directly communicated expectations concerning mathematical content, teaching, learning, and assessment. Including all sections of the documents might have produced different coding frequencies. Second, the findings were shaped by the Mathematical Knowledge for Teaching framework, and the use of an alternative framework for analysing teacher knowledge might have produced different interpretations. Third, the MKT framework was developed primarily within the United States and may not fully capture all forms of knowledge relevant to mathematics teaching in the Ghanaian Senior High School context. Finally, the study was based principally on curriculum documents, while the Chief Examiners' reports were used only as supplementary contextual evidence. The findings therefore describe the teacher-knowledge expectations made visible in the written curricula and cannot determine how teachers interpret or enact those expectations in classroom practice.

Future research could extend the analysis to the complete curriculum documents, examine whether a context-specific conception of MKT is needed for Ghanaian mathematics teachers, and use teacher interviews, classroom observations, or lesson materials to investigate how the knowledge expectations identified in the curriculum are enacted in practice.

CONCLUSION

This study examined Ghana's transition from the 2010 Objective-Based Senior High School Mathematics Curriculum to the 2023 Standards-Based Senior High School Mathematics Curriculum through the lens of Mathematical Knowledge for Teaching. The findings show that the reform has broadened the teacher-knowledge expectations made visible in the written curriculum, particularly by increasing the relative emphasis on pedagogical and interpretive knowledge.

The study demonstrates that curriculum reform changes not only what students are expected to learn but also what teachers are expected to know and do. Successful implementation of the Standards-Based Curriculum will therefore require sustained teacher preparation, professional development, appropriate instructional resources, and assessment practices aligned with the curriculum's learner-centred expectations.

By applying the MKT framework to curriculum documents, the study also provides a useful approach for examining how curriculum reform reshapes the professional knowledge expected of teachers. Future research should investigate how these expectations are interpreted and enacted in Ghanaian mathematics classrooms.

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