



International Journal of Learning, Teaching and Educational Research
 Vol. 25, No. 5, pp. 969-992, May 2026
<https://doi.org/10.26803/ijlter.25.5.43>
 Received Jan 15, 2026; Revised Feb 20, 2026; Accepted May 20, 2026

The Triple Helix of Curriculum Reform in Secondary Mathematics Education: Teacher Agency and the Integration of Indigenous Knowledge Systems in Post-Apartheid South Africa

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Abstract. Reform of the mathematics curriculum in post-apartheid South Africa has involved sustained efforts to redress historical inequalities and forms of epistemic exclusion. Despite these initiatives, the integration of Indigenous Knowledge Systems (IKS) into formal mathematics education remains uneven and, in many cases, largely symbolic. This paper draws on the Triple Helix framework to examine curriculum reform as an interactive process involving government, higher education institutions, and teacher-related agencies. Particular attention is given to mathematics teacher agency, which is examined as a central factor influencing how curriculum reforms are interpreted and implemented at the secondary school level. Using a qualitative, non-empirical critical analysis of policy documents and relevant literature, and guided by interpretivist and critical research traditions, the study shows that although IKS has gained recognition within national curriculum policies, a noticeable gap persists between policy intentions and classroom practice, especially in mathematics instruction, assessment, and teacher preparation. The analysis further indicates that hierarchical relationships within the Triple Helix structure often undervalue teachers' experiential knowledge and cultural perspectives, limiting their ability to design and implement contextual meaningful mathematics curricula. The paper contributes to ongoing discussions on meaningful IKS integration by proposing a partnership-oriented and culturally grounded model of teacher professional learning. It also argues that stronger alignment between curriculum policy, assessment practices, and teacher education is necessary

Citation :
 Fekumo, B., & Phoshoko, M. M. (2026). The Triple Helix of Curriculum Reform in Secondary Mathematics Education: Teacher Agency and the Integration of Indigenous Knowledge Systems in Post-Apartheid South Africa. *International Journal of Learning, Teaching and Educational Research*, 25(5), 969-992. <https://doi.org/10.26803/ijlter.25.5.43>

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to position teacher agency as a genuine driver of curriculum innovation in post-apartheid South African mathematics education.

Keywords: Curriculum Reform; Indigenous Knowledge Systems; Mathematics Teacher Agency; Triple Helix Framework; South African Education

1. Introduction

Ever since the South African education system was restructured after apartheid ended in 1994, a continuous curriculum reform has been underway to address past wrongs and to make schooling reflect the constitutional principles of equity, human dignity, and social justice (Gumede & Biyase, 2016; Jansen & Taylor, 2003). Reform after reform, including Curriculum 2005 and the National Curriculum Statement, Curriculum and Assessment Policy Statements (CAPS), have attempted to set up uniform learning expectations alongside facilitating inclusivity and relevance in a variety of schooling conditions (Molapo & Pillay, 2018). These reforms indicate a multi-actor system of governance where national policymakers, institutions of higher education, and agencies of educators interact to create a curriculum design and implementation akin to a Triple Helix system of policy formulation, knowledge production, and professional practice (Hoadley, 2017).

In spite of these reform aspirations, studies have always shown that curriculum policy will not always be converted into consistent classroom practice. Post-apartheid curriculum change studies show that frameworks like CAPS describe learning outcomes and content standards, but their practice is mediated by teachers and their interpretive work and professional judgement and other contextual constraints that lead to unequal implementation of these frameworks across schools (Mauda, 2016; Molapo & Pillay, 2018). In this mediation process, teacher agency, which refers to the ability of teachers in decoding policy, professional discretion, and adaptability of curriculum to situational needs, is identified as one of the key factors in determining how reforms are realized in practice (Organization for Economic Co-operation and Development (OECD), 2025).

Notably, teacher agency is relevant as far as the inclusion of Indigenous Knowledge Systems (IKS) within formal education is concerned. IKS are also gaining recognition as legitimate knowledge systems based on the cultural, historical and ecological context of local peoples, but which colonial and apartheid education systems historically marginalized (Khupe, 2020). Despite the official recognition of the importance of IKS in CAPS and allied policy frameworks, especially in the context of mathematics and science education, where indigenous numeracy practices, spatial reasoning, measurement, and patterning intersect with formal mathematical knowledge, academics observe that Western knowledge systems still prevail in the organization of the curriculum, teaching and learning strategies, and assessment

(Bhuda & Maditsi, 2025). Accordingly, the additive presence of IKS tends to be fringe, symbolic or selectively performed.

The scholarly community believes there is a significant educational value in the meaningful integration of IKS. Research has suggested that applying indigenous epistemologies may enhance the relevance of the curriculum, particularly the mathematics curriculum, enhance cultural identities of the learners, enhance engagement and ensure epistemic justice by legitimizing other ways of knowing in schooling (Keane et al., 2023; Miuka & Tufu, 2025). Nonetheless, empirical research in South Africa indicates that the enactment of classes has continued to face problems related to inadequate operational directions, inefficient classroom resources, and weak preparation of teachers to interact with indigenous knowledge frameworks (Jaxa, 2024; Opoku & James, 2021). The limitations put teachers, specifically the mathematics teacher, in the heart of a policy practice paradox, in which they are supposed to effect IKS integration, but they lack the institutional nurturing they would require substantively (Madlela, 2022).

The persistent gap between policy recognition and teacher practice informs the need to research curriculum reform as neither a policy nor a design activity, but as a mediated epistemological practice that is affected by power relations, institutional alignment, and teacher agency (Priestley et al., 2012; Biesta et al., 2015). Although the role of teacher agency is recognized in the literature, there is a gap in theoretical research that places teachers within the framework of multi-actor governance dynamics of curriculum reforms, challenging the facilitation or restriction of their epistemic power in the implementation of Indigenous Knowledge Systems.

This paper is guided by the following research questions:

1. How do the interacting dynamics among government, higher education institutions, and teacher agencies within the Triple Helix system shape the possibilities for integrating Indigenous Knowledge Systems into South African secondary mathematics education?
2. In what ways does mathematics teacher agency mediate between formal curriculum policy requirements and authentic IKS integration in classroom practice?
3. What structural reforms to the Triple Helix of curriculum governance are necessary to transform symbolic IKS policy recognition into substantive pedagogical practice?

Despite substantial scholarship on post-apartheid curriculum reform (Gumede & Biyase, 2016; Hoadley, 2017; Jansen & Taylor, 2003) and increasing attention to Indigenous Knowledge Systems (IKS) in South African education (Madlela, 2022; Onwu & Mosimege, 2004; Opoku & James, 2021), no study has systematically applied the Triple Helix framework to examine how interactions among state structures, higher education institutions, and teacher formations shape the conditions for IKS integration in mathematics education. This absence is significant because it leaves insufficiently theorised the structural power relations, institutional configurations,

and agency conditions that influence whether IKS shifts from policy commitment to classroom practice. This paper responds in three ways. It offers a structural account of the persistent gap between IKS policy intentions and classroom enactment in mathematics education. It repositions mathematics teacher agency as a central epistemic resource for reform. It also extends the relevance of the Triple Helix framework to curriculum governance in postcolonial contexts.

2. Methodology

2.1 Research Design and Paradigm

The research adopts a qualitative, non-empirical critical policy and literature analysis (Bowen, 2009; Merriam & Tisdell, 2016). It is based on the interpretivist and critical paradigm of research. Using interpretivism helps to comprehend the socially constructed meanings that the actors of the curriculum reform system attach to the Indigenous Knowledge Systems (IKS) integration, whereas the critical paradigm questions the power relations, structural inequalities, and epistemic hierarchies, which shape the assigned meanings (Creswell & Creswell, 2018). The design is fitting since the research does not intend to create new empirical data among teachers or schools, but rather it critically examines existing literature, policy documents, and theoretical frames in order to create insights into the systemic conditions influencing IKS integration of mathematics education in South Africa.

2.2 Data Sources and Selection

There are three major sources of the analytical corpus. First, the government's intent in the Triple Helix system is represented by national curriculum and policy documents such as the Curriculum and Assessment Policy Statements (CAPS), policy documents of the Department of Science and Innovation (the Indigenous Knowledge Systems Policy, DSI, 2019), and legislation. Second, the literature sources on mathematics curriculum reform, teacher agency, and IKS integration in South Africa were located by searching ERIC, Google Scholar, and JSTOR with the following terms: Indigenous Knowledge Systems AND mathematics AND South Africa, teacher agency AND curriculum reform AND South Africa, Triple Helix AND education. Relevancy, methodological rigour, and recency (2000-2025) were prioritised during selection. Third, global academic sources concerning the Triple Helix model, teacher agency theory, and postcolonial theory were included to offer theoretical premises of the analysis.

2.3 Analytical Procedure

The analysis process occurred in three stages in line with the critical policy analysis approach (Bacchi, 2009). The first stage involved a close textual analysis of policy documents in order to determine how it is possible that IKS is framed, positioned, and operationalized (or not) within the formal curriculum framework, where there is a focus on the language of inclusion, procedural specificity, and assessment alignment. The second phase involved the thematic analysis of the empirical and theoretical literature to map the available evidence on teacher agency, IKS integration practices as well as structural barriers throughout the three spheres of Triple Helix.

The third stage involved the use of the Triple Helix framework as an analytical prism to explain the observed patterns, which showed how relations of power, structural incompatibilities, and agency situations interplay to create the identified gap between IKS policy aspirations and classroom realities. The Ecological Model of Teacher Agency and Postcolonial Theory as secondary theoretical lenses were used to further the level of the interpretive analysis to draw on individual teacher responses and historical epistemic hierarchies, respectively.

2.4 Trustworthiness

The trustworthiness of this non-empirical analysis was ensured through four strategies (Lincoln & Guba, 1985): credibility was established through triangulation of multiple literature sources and policy documents; transferability was supported by providing sufficiently thick description of the South African context to allow readers to assess applicability to analogous contexts; dependability was strengthened through transparent documentation of the analytical procedure described above; and confirmability was ensured by grounding all interpretive claims in specific textual evidence from the cited literature and policy documents.

2.5 Ethical Considerations

To ensure the responsible use of knowledge, respect towards Indigenous Knowledge Systems (IKS), and academic honesty, even though in this study no primary data was collected and no human subjects were involved, the ethical principle was strictly followed. To make sure that the evidence about teacher agency and IKS integration is theoretically sound, culturally and ethically accountable.

3. Literature Review

3.1 Theoretical Framework

The theoretical framework of this paper is hierarchically organized in order to guarantee analytical clarity. The model that is predominantly used is the Triple Helix (Etzkowitz & Leydesdorff, 1995, 2000), which is a structural lens that is used in analyzing an interaction between government, institutions of higher learning, and teacher agencies as the reform of the mathematics curriculum in South Africa. The Ecological Model of Teacher Agency (Biesta et al., 2015; Priestley et al., 2015) and the Postcolonial Theory (Hickling-Hudson, 2010; Vandeyar, 2020) are secondary lenses within this framework, which can be used to explain the differences in teacher agency and the maintenance of epistemic inequalities.

The Sociocultural Theory (Lipponen & Kumpulainen, 2011) ties the practice of knowledge of teachers to historical and cultural backgrounds. The Quadruple Helix (Carayannis et al., 2012; Hossain et al., 2023) builds on the analysis of the Triple Helix with the central focus on the civil society and indigenous knowledge holders. The substantive point of focus is that of Indigenous Knowledge Systems (IKS), or the content of the curriculum that is being studied as opposed to a theoretical spectrum. This stratified methodology makes every component have a specific purpose of analysis.

Within mathematics education, the Triple Helix shows how mathematics curriculum policies, teacher education in mathematics, and classroom enactment interact to shape the possibilities for integrating Indigenous Knowledge Systems. It is also possible to conduct a systematic examination of power asymmetries, structural misalignment, and the circumstances in which the policy instructions can be converted into classroom practice using the Triple Helix (Seleke et al., 2025; Etzkowitz & Leydesdorff, 2000). In particular, it shows how the government sets priorities of policies, universities justify knowledge, and teachers implement or mediate curriculum innovations in the classroom, which gives a good perspective on why IKS tends to be symbolically present, but not substantially (Madlela, 2022; Shabalala et al., 2025).

In order to explain the difference in the teacher application of IKS, the paper relies on the Ecological Model of Teacher Agency. According to this model, agency is formed when the beliefs, goals, and knowledge of a teacher come into conflict with the enabling or restrictive structures of the professional environment, such as resources, school policies, and professional culture (Ramberg, 2014; Yakavets et al., 2023). This lens, combined with the Sociocultural Theory, which previews cultural and historical context of learning and social interaction (Photo & McKnight, 2024), is why the ability of teachers to merge IKS varies even in the same policy climate (Lipponen & Kumpulainen, 2011; Priestley et al., 2012).

Postcolonial Theory fills in these views by offering a critical prism through which to examine the long-term effects of Western epistemic hegemony of South African schooling. It understands how the marginalization of indigenous knowledge and teacher epistemic authority is an extension of colonial hierarchies of knowledge validation (Hickling-Hudson, 2010; Vandeyar, 2020). The postcolonial lessons help to understand the need to identify and facilitate teacher agency as a place of curricular mediation and cultural knowledge translation in situations where structural constraints and policy gaps hamper the incorporation of authentic IKS (de Beer & Van Wyk, 2012; Onwu & Mosimege, 2004).

Although the Quadruple Helix Model is given due credit, it is mentioned tactically as an interpretive add-on, but not as the guiding principle. The Quadruple Helix identifies possible sources of community engagement, professional learning, and curriculum co-design, which can strengthen teacher agency and contextual relevance, by incorporating the civil society actors, including indigenous knowledge holders, local elders and community, and local organizations, in addition to the traditional Triple Helix spheres of government, higher education, and industry (Carayannis et al., 2012; Hossain et al., 2023; Shyiramunda & van den Berselaar, 2024).

The Triple Helix serves as the analytical core of this multi-layered model, and the Ecological Model of Teacher Agency and Postcolonial Theory provides the basis for interpreting why, how, and under what circumstances teachers mediate IKS integration. This framework enables the exploration of systemic, institutional, and

pedagogical dynamics in a systematic manner and provides a critical foundation for policy, professional development, and culturally responsive curriculum reform in post-apartheid South Africa.

3.2 Indigenous Knowledge Systems and Teacher Mediation in South African Curriculum Reform

Literature has widely defined Indigenous Knowledge Systems (IKS) as dynamic and contextual epistemologies comprising the knowledge, skills, practices and worldviews that are formed by indigenous communities through their long-standing interactions with the social, cultural and ecological environment. Instead of being fixed or pre-scientific traditions, IKS are coherent bodies of knowing that produce localized explanations of both natural and social phenomena, especially in environmental management, health, agriculture and social organization (Madlela, 2022; Ogunniyi, 2011; Zidny et al., 2020). The IKS is becoming progressively understood as an acceptable mode of knowledge production within the South African educational discourse, which can productively coexist with and critically intersect Western scientific traditions, thereby expanding the basis of epistemologies of formal schooling.

Such an intellectual acknowledgment is institutionalized in the post-apartheid curriculum policy guidelines. In specific areas, such as Natural Sciences, Life Sciences, Geography, Social Sciences, and Mathematics, the national policy instruments, especially the Curriculum and Assessment Policy Statements (CAPS) actually recognize the importance of indigenous knowledge, where learners are invited to negotiate scientific ideas with the local knowledge practices (Curriculum Perspectives, 2024; Department of Basic Education [DBE], 2011). In addition to the education sector, the national programs managed by the Department of Science and Innovation also make IKS a strategic national tool associated with research, innovation, and sustainable development (Department of Science and Innovation (DSI), 2019). Altogether, such policy developments are pointers to the decisive change in the direction of epistemic inclusion and decolonization in the South African education system.

Nevertheless, even in the face of this acknowledgment of the policy, there remains a consistent gap in implementation that still defines the practice of IKS in classrooms. Although CAPS requires indigenous knowledge integration, it does not include much procedural advice on how teachers must choose, contextualize and evaluate IKS content, in effect leaving the practice to the interpretation and discretion of the professionals (Madlela, 2024). This has led to IKS integration being uneven, fragmented, or symbolic, which depicts a deeper disjuncture between the policy intentions of curriculum and pedagogical actions. This disparity is also exacerbated by the lack of instructional resources, the lack of alignment between IKS-based pedagogy and standardized assessment regimes and the lack of alignment between curriculum pacing demands and the dialogical, context-based nature of indigenous knowledge.

The teacher agency is the most important mediating variable between policy recognition and classroom practice. The role of teachers is central to the process of interpreting the curriculum requirements, the translation of abstract policy statements into the pedagogical practice, and the negotiation of the conflicts between the standardized curricular requirements and the knowledge forms that are rooted in the locality. Empirical and conceptual literature points out that most South African educators attach importance to the use of IKS and make an effort to include indigenous illustrations, local customs, or previous understanding of pupils in their instruction (de Beer & Van Wyk, 2012; Madlela, 2024; Onwu & Mosimege, 2004). Nevertheless, the capacity of the teacher to take significant agency is frequently constrained by the lack of explicit training in indigenous epistemology because pre-service and in-service teacher education programs usually provide little exposure to IKS or culturally responsive pedagogies (Opoku & James, 2021).

The determination of the extent to which teacher agency can aid in authentic IKS integrational is therefore exhaustive on professional development, curriculum promotion and policy translation. In the case of structured professional development programs that clearly involve teachers in indigenous knowledge material, pedagogical practices, and assessment strategies, teachers show greater confidence and ability to go beyond the superficial inclusion into deeper epistemological involvement (Madlela, 2022). Without this sort of support, though, teachers are left to find their own way regarding policy expectations, in most cases leading to ad-hoc or tokenistic attempts to incorporate IKS that meet the demands of curriculum requirements but do not disrupt the existing epistemic dominances.

One of the primary tensions in teacher mediation of IKS integration lies in the contradiction between the standardized structures of the curriculum and the contextual, community-based nature of indigenous knowledge. Centralized curricula and high-stakes assessment systems prioritize uniform content coverage and standardized knowledge representation, often at the expense of knowledge that is oral, embodied, or locally rooted (Shabalala, 2025; Tariq, 2025). Teachers navigating these constraints may find that incorporating IKS is pedagogically valuable yet institutionally misaligned with assessment priorities and accountability demands, limiting the scope of their professional agency (Tariq, 2025). In this way, teacher agency becomes both the driver of epistemic inclusion and the point where structural restrictions limit the depth and authenticity of IKS integration.

This analysis highlights the point that the difficulty in integrating Indigenous Knowledge Systems into South African curricula is not one of conceptual familiarity or policy desire, but rather one of mediated practice. The teacher agency is the most important agent that makes IKS policy aspirations either become embodied or disembodied in practice, making teachers the most important actors in translating curriculum reform into meaningful epistemic change.

3.3 Understanding the South African Triple Helix Model of Curriculum Reform

The Triple Helix model was initially an innovation research model of conceptualization, which evolved into a theoretical framework used to describe the dynamic processes of interaction between government, universities, and industry in the application and production of knowledge in contemporary knowledge-based economies (Leydesdorff, 2010). The model suggests that innovation is not a one-way activity of an isolated institution, but recursive, overlapping, and co-evolutionary relationships between the three spheres, with each sphere potentially taking the place of the other over time in part (Etzkowitz & Leydesdorff, 1995; Etzkowitz & Leydesdorff, 2000).

At the center of the framework is the notion that universities are more than teaching and research, governments are more than regulators and can act as facilitators and coordinators, and professional or productive sectors can provide knowledge and feedback to policy and practice (Etzkowitz, 2008). Though initially used to refer to science, technology, and economic development, the Triple Helix is identified as an adaptable analytical prism that can be used to shed light on governance and reform processes in other areas of the public, such as education (Cai & Etzkowitz, 2020).

Triple Helix model which was initially conceptualized by Etzkowitz and Leydesdorff in 1995 notes that government, universities and industry boundaries have become more permeable and mutually dependent in knowledge-based economies (Etzkowitz & Leydesdorff, 1995). In contrast to linear innovation models, the Triple Helix explains a recursive and co-evolutionary dynamic, according to which each sphere may take up the characteristics of the other, universities in the economic development, governments in the knowledge creation, and industry in the education (Etzkowitz, 2008; Cai & Etzkowitz, 2020). The model is used in South African mathematics curriculum reform to make change an agenda of negotiation involving the government policy, higher education, and teacher agency, and it provides more insight into the achievements and failures of implementation.

Since the model was developed, researchers have started to apply the Triple Helix model to education systems and curriculum reform, claiming that educational change also relies on continuous engagement of the policy actors, knowledge producers, and practitioners (Zakaria et al., 2023). The sphere of industry, in the modified interpretation, regularly incorporates professional communities, schools, and teacher organizations, whose applied experience and knowledge on the ground influence the implementation of reforms (Cai, 2014; Galvao et al., 2019). Researchers in education have argued that the curriculum reform processes are comparable to innovation systems because they entail policy development, translation of knowledge, practice, and feedback processes across institutional lines (Cai & Etzkowitz, 2020).

In this sense, curriculum is not considered to be a policy product that is fixed; rather, it is a product of negotiation through interaction between the government and institutions of higher learning that prepare teachers and conduct research, and

professional teacher agencies that implement classroom practices (OECD, 2025). This transformation foreshadows the importance of relational rule and shared responsibility in making sense of how curricular reform does or does not "take hold". In a Triple Helix model with an education focus, the government, higher education institutions, and teacher agencies have a separate, yet mutually reliant role in curriculum reformation (Cai & Etzkowitz, 2020). The governments define the priorities of the policies, regulatory systems, and standards of the curriculum, which express national educational objectives and societal values (Department of Basic Education [DBE], 2011; Gumede & Biyase, 2016).

Higher education institutions also play the role of researching curriculum, training teachers, and creating pedagogic knowledge, which guides the design of reform and professional education (Cai & Etzkowitz, 2020; Jansen & Taylor, 2003). Teacher agencies, as multi-individual teachers, professional associations, unions and subject associations, are mediators of reform as it occurs in the point of practice, by interpreting, adapting and implementing curriculum policy in a variety of classroom situations (OECD, 2025). These actors do not act in a linear manner, but instead, they relate to each other, and feedback mechanisms of the implementation of the reform in classrooms shape policy revision and research agendas, thus supporting the principle of the Triple Helix of mutual shaping and the production of the reform.

Triple Helix model is especially applicable to South African curriculum reform since it reflects the complexity of multi-actor multi-cycle processes, which have taken place since 1994. The reforms in curriculum have included Curriculum 2005 to the National Curriculum Statement and CAPS, which have had coordinated and inconsistent roles: government establishment of policy priorities, universities and research institutes generation of pedagogical and disciplinary knowledge, and negotiation of application by teachers in highly unequal school environments (Gumede & Biyase, 2016; Hoadley, 2017; Jansen and Taylor, 2003).

Inconsistency of teacher capabilities, contextual differences, and disparity between policy intent and classroom realities explain the challenges of reform being seen as an interactive process of governance, instead of top-down policy implementation (OECD, 2025). Using the Triple Helix framework can shed light on the relationship between state power, academic knowledge, and teacher agency, and the effects of all this on curriculum outcomes (especially in terms of equity, decolonization, and Indigenous Knowledge Systems inclusion).

3.4 Mathematics Teacher Agency as a Mediator of Curriculum Reform

The concept of teacher agency has become central to modern curriculum studies because it clarifies the active role that teachers play in curriculum design, interpretation, and implementation, rather than passively executing policies designed and imposed by others (Ponnusamy, 2017). Teacher agency, as a concept, is explained by the ability of teachers to make mindful and thoughtful decisions that shape teaching and learning in particular structural and cultural contexts (OECD,

2025; Priestley et al., 2015). This school of thought places agency as an ecological and relational process, which is aided by the dynamic between the professionals' beliefs, knowledge and identities of teachers and the institutional, policy and material circumstances that they operate in (Biesta et al., 2017). Teacher agency thus takes place at the center of the translation of policy texts into classroom practice in a curriculum reform context since teachers use their professional judgement to read curricular intentions, choosing the content to be taught, and modifying pedagogical strategies to individual needs (Hoadley, 2017; Priestley et al., 2015).

With this conceptualization, mathematics teachers act as both implementers, interpreters and creators of curriculum change. They are supposed to conform to national curriculum frameworks and assessment standards as the implementers of classrooms, but as has been mentioned in Hoadley (2017) and Jansen and Taylor (2003), teachers do not implement policy linearly and mechanically. Rather, teachers are seen as interpreters who construct meaning out of curriculum texts in terms of what they already know, believe, and what reality requires, leading to diverse implementations of supposedly identical curriculum policies (Priestley et al., 2015). In most instances, the teachers also become the innovators of curriculum adaptations, which might alter the contents, sequence the learning experiences and incorporate the examples that are locally relevant in order to fill the gaps in policy anticipations and classroom realities (OECD, 2025). Such multiplicity of roles highlights the importance of mathematics teacher agency in deciding the success or failure of mathematics curriculum reforms, especially where there exist diversity and inequality.

The practical significance of mathematics teacher agency in IKS integration can be illustrated through the following example drawn from the literature. In South African mathematics classrooms, indigenous practices such as the geometric patterning found in Ndebele beadwork and mural art directly align with formal curriculum outcomes in transformation geometry, symmetry, and tessellation (de Beer & Van Wyk, 2012; Ogunniyi, 2011). A mathematics teacher with high agency and adequate professional preparation can leverage these connections by designing tasks that require learners to analyze the geometric properties of culturally familiar patterns before applying formal mathematical notation – thereby simultaneously validating indigenous knowledge and developing formal mathematical competency.

However, as Madlela (2022) documents in research conducted in KwaZulu-Natal schools, teachers who lack specific training in indigenous epistemologies and culturally responsive pedagogy either omit such connections entirely or include them superficially as decorative examples rather than substantive mathematical content. This contrast illustrates how the presence or absence of teacher agency – shaped by professional preparation, institutional support, and curriculum guidance – determines whether IKS appears in the mathematics classroom as meaningful epistemological engagement or tokenistic acknowledgment.

However, mathematics teacher agency does not exist in a vacuum, but rather structural, professional, and contextual factors influence mathematics teacher agency and constrain its ability to act (Biesta et al., 2015). Constitutionally, the autonomy of mathematics teachers and the opportunities for professional judgment can be restricted by structural elements, namely curriculum centralization, high-stakes assessment regimes, and accountability pressures (Hoadley, 2017; OECD, 2025). At the workplace, teacher education of quality, continuous professional growth, and a community of professionals also boost teacher confidence and competence in engaging in curriculum reform in a meaningful way (Biesta et al., 2017; Priestley et al., 2015).

The level of the agency that teachers may exercise in practice is also influenced by contextual factors: school leadership, availability of resources, the size of classes, and socio-economic conditions, especially in historically disadvantaged South African schools (Gumede & Biyase, 2016; Jansen & Taylor, 2003). Such interacting conditions contribute to the explanation of the common uneven effects of mathematics curriculum reforms on schools and regions with similar policy prescriptions.

The implications of an agency of limited or increased mathematics teachers are especially important to the incorporation of mathematics Indigenous Knowledge Systems in the formal curriculum. According to Madlela (2022), the South African curriculum policies appreciate the importance of IKS. However, the level to which teachers are prepared, willing, confident and able to implement indigenous epistemologies is pivotal to classroom integration (Miuka & Tufu, 2025). Where teacher agency is curtailed by tight curriculum timelines or poor professional preparedness and provision of instructional resources, the integration of IKS is generally tokenistic, supporting the disjuncture between policy goals and classroom practice (Hoadley, 2017; Madlela, 2022).

On the other hand, teachers are conducive to using the knowledge of the community, local contexts, and culturally responsive pedagogies in the integration of IKS in a manner that enhances learning and affirms the identity of learners when they are empowered as knowledgeable and independent professionals (OECD, 2025; Ogunniyi, 2011). This helps in the argument that enhancing mathematics teacher agency is not only a professional issue, but it is a prerequisite to the actualization of the transformative curriculum aims, such as the epistemic inclusion and decolonization of South African education, mathematics education in particular.

3.5 Power, Policy, and the Limits of Symbolic Inclusion: Towards a Responsive Reform

Although the Triple Helix framework is a helpful conceptual framework used to understand curriculum reform as a three-way interactive process involving government, higher education institutions, and teacher agencies, the application of the framework to the Indigenous Knowledge Systems (IKS) integration indicates the existence of an ongoing power imbalance, which undermines the opportunity of

bringing about meaningful epistemic transformation (Cai & Etzkowitz, 2020). The initial assumption of the Triple Helix is rather balanced and reciprocal relationships between the actors (Etzkowitz & Leydesdorff, 2000); in reality, reform processes in South Africa curriculum reform are mostly characterized by subordinated affective and contextual expertise of teachers and obscured by governmental requirements of reforms (Seleke et al., 2025). Such an imbalance has specifically far-reaching implications on IKS integration, whereby epistemologies not within the prevailing Western traditions must be explicitly institutionally legitimized and pedagogically mediated in order to be legitimized in formal schools.

In such an unequal arrangement, teacher agencies often take a much more structurally subservient role in which they are supposed to implement curriculum changes without having any substantive influence in the formulation of their own epistemological bases. Though the policies of the curriculum formally acknowledge IKS and foster the idea of cultural diversity and knowledge pluralism, they often do not have explicit mechanisms through which these promises are translated into classroom practice, professional learning and assessment design (Shabalala et al., 2025). Consequently, policy talk seems to be at the figurative levels, whereas teachers are left to broker implementation in closely controlled curricular and accountability frameworks. This tendency is indicative of a wider tendency towards curriculum reform of privileging macro-level policy coherence over meso- and micro-level pedagogical reality and restricting the ability of teachers to make epistemic judgement and innovation (Hoadley, 2017; Priestley et al., 2012).

One of the main limitations of the authentic IKS integration is the marginalization of teacher epistemic authority (Hanon, 2012). The teachers hold situated, experiential and in many cases, culturally instilled knowledge that is essential to the contextualization of indigenous epistemologies in the classroom practice. However, this tactic is hardly viewed as a credible source of curriculum change, especially in a system that runs on standardized specifications of content and testing regimes (Seleke et al., 2025; Madlela, 2024). Even if teachers wish to integrate IKS, their access to suitable resources that are in line with curriculum implementation, insufficient training on indigenous epistemologies, and institution-wide cultures that are supportive of compliance rather than professional judgement tend to limit the choices they can make (Hoadley, 2017). As a result, educators are placed in roles of implementers, as opposed to co-creators of curriculum knowledge, to support epistemic practices that elevate formal policy and academic authority above classroom-based expertise.

The implications became more compounded by structural misalignment between curriculum policies, assessment regime and professional development. Although policy documents promote working with indigenous knowledge, evaluation systems still give more prestige to standardized learning outcomes and traditional ways of knowledge representation that do not fit well into the contextual, dialogue, and often oral IKS (Hoadley, 2017; Tariq, 2025). Meanwhile, the models of professional

development are mostly compliance-based, emphasizing the coverage of the curriculum rather than providing teachers with epistemological knowledge and pedagogical skills to interact with indigenous knowledge systems (Madlela, 2022). Such systemic incoherence produces tokenistic inclusion, wherein the teachers are compelled to juggle policy demands with their assessment-based demands and little institutional assistance.

These shortcomings can be overcome by reorienting the Triple Helix to a much better responsive and epistemically balanced reform. This type of framework would rebrand teacher agencies as core facilitators of curriculum change, not the peripheral executors, and acknowledge their professional and cultural expertise as a valid source of curriculum enlightenment. This involves providing institutional spaces that allow teachers to be engaged in the curriculum design, review, and evaluation processes in a meaningful way aligned with scholarship on teacher agency, highlighting the significance of professional autonomy and spaces to manoeuvre in facilitating change (Priestley et al., 2012; Biesta et al., 2015). Incorporating teachers in the core of the reform process would make the mediating role of the Triple Helix more robust and would increase the transfer of the policy aspirations to pedagogically significant practices.

Another significant factor is reinforcing the working relationships between the government, institutions of higher learning, teaching staff, and indigenous people. According to research, co-production of curriculum knowledge by long-term collaboration is the most effective way to integrate authentic IKS (as opposed to one-way flow of policy or academia to schools) (Aikenhead & Michell, 2011; Madlela, 2022). Nevertheless, such partnerships are still mostly ad hoc in South Africa, which restricts their systemic influence. Community-based scholarship, school-university liaisons, and collaborative models of professional learning should be institutionalized in order to match higher education research capacity with the pedagogical demands of teachers and culture-specific contexts of learners and ensure epistemic coherence in the triadic configuration of the Triple Helix (Hossain et al., 2023).

The limits to the symbolic inclusion do not reside in conceptual vagueness or lack of authorization of policy, but within power relations and structural contradictions from the curriculum reform ecosystem. As long as power asymmetries are not actively tackled, the importance of teacher epistemic authority is not an issue of valuation, and unless this is done, curriculum, assessment, and professional development are all far too closely aligned, IKS integration will remain limited by the systems that are supposed to foster it. To bring about the kind of change required, then, a reform paradigm geared towards responsive system-level change will not be achieved through superficial rhetorical gestures in ways that would enable the Triple Helix to actually emerge as an effective joint instrument of remediating processes as part of epistemic justice and curricular redesigning for South African education.

4. Discussion and Implications

This paper demonstrates that the Triple Helix framework offers a coherent and analytically robust lens for understanding curriculum reform and the integration of Indigenous Knowledge Systems (IKS) in South Africa. It illuminates how relationships among government, higher education institutions, and teacher agencies shape both the possibilities and constraints of reform within secondary mathematics education.

Section 4.1 analyses the interacting dynamics within this governance structure, focusing on how power relations, institutional arrangements, and structural misalignments influence the conditions under which IKS can be meaningfully incorporated into the mathematics curriculum. Section 4.2 examines the mediating role of mathematics teacher agency, highlighting how teachers interpret, negotiate, and enact formal curriculum policy in their efforts to integrate IKS authentically in classroom practice. Section 4.3 identifies the structural reforms required to reposition the Triple Helix as a responsive and collaborative system capable of supporting sustained pedagogical change. Together, these sections clarify the institutional shifts necessary to move IKS from symbolic policy inclusion to substantive curriculum enactment.

4.1. Asymmetries in power and Structural Misalignment.

Analysis reveals persistent power imbalances within the curriculum reform process: government policy sets the priorities of the curricular one, higher education justifies knowledge based on research and teacher education, and teachers are supposed to implement reforms without the necessary structural support. Such asymmetries are further heightened through structural inequality within policy, evaluation, and support systems that typically stifle the agency of teachers as well as limit levels of integration of IKS (Seleke et al., 2025; Shabalala et al., 2025). In turn, IKS is also commonly mentioned in policy documents, yet it is poorly implemented in classrooms, which indicates not a substantive but a symbolic integration.

Table 1: Structural barriers to IKS integration across Triple Helix spheres

Triple Helix Sphere	Key Structural Barrier	Impact on IKS Integration	Proposed Response
Government	Policy recognition without procedural guidance	Symbolic, fragmented IKS inclusion	Develop implementation frameworks with clear guidelines
Higher Education	Compliance-based teacher education	Limited teacher capacity for IKS pedagogy	Redesign pre-service and in-service programs
Teacher Agencies	Accountability pressures and resource constraints	Tokenistic IKS integration	Institutionalize teacher epistemic authority
Cross-Helix	Power asymmetries favoring formal knowledge	Marginalization of indigenous epistemologies	Responsive Triple Helix reform paradigm

Table 1 summarizes the key structural barriers to IKS integration across the three Triple Helix spheres, together with their observed impacts and proposed responses.

4.2 Mathematics Teacher Agency as Central Epistemic Mediator

Drawing on the synthesis of empirical literature reviewed in Section 3, and interpreted through the Ecological Model of Teacher Agency and the Triple Helix framework, this section theorizes mathematics teachers as active epistemic mediators rather than passive policy recipients, a position supported by convergent evidence from multiple empirical studies conducted in South African and comparable postcolonial educational contexts (de Beer & Van Wyk, 2012; Hoadley, 2017; Madlela, 2022; Onwu & Mosimege, 2004; Priestley et al., 2015).

In this way, the study re-imagines mathematics teachers as active epistemic mediators by placing mathematics teacher agency (against an image of complicit or obedient policy-takers) in the Triple Helix system. Teachers are interpreting and adjusting the metaCurriculum that includes content from the curriculum in response, mediating policy demands with local knowledge and pedagogical truths (Flessner & Kandel-Cisco, 2019; Sang et al., 2022). The Ecological Model of Agency demonstrates the diversity of mathematics teacher responses: agency is constituted by individual convictions, professional self, institutional sources, and time or context limitations (Ramberg, 2014; Yakavets et al., 2023). The postcolonial theory also describes how the marginalization of teachers in the decision-making process has been perpetuating Western epistemic power, diminishing the effectiveness of indigenous knowledge in formal education (Hickling-Hudson, 2010; Vandeyar, 2020).

4.3 Implications for Policy, Professional Development, and Teacher Engagement

The Triple Helix framework illustrates that the genuine incorporation of Indigenous Knowledge Systems (IKS) in South African mathematics education is impossible in the case of interventions in one sphere. Reform demands coordinated, consistent effort on the part of government policy and the institutions of higher education as well as teacher agencies.

4.3.1 Policy Consistency

To ensure the Triple Helix as a means of curricular transformation and not an image of compliance, there should be substantial correspondence among curriculum policy, assessment regimes, and professional development structures. Although IKS is recognized in the content of CAPS, standardized tests still privilege Western forms of knowledge, favoring abstracted and mathematical forms of knowledge over the oral, situated, and embodied forms in which indigenous knowledge is expressed (Hoadley, 2017; DSI, 2019). This produces a paradoxical situation: educators are motivated to incorporate IKS but are punished when it does not cover the standardized content. To address it, the Department of Basic Education needs to work on clear assessment frameworks that acknowledge IKS-informed problem-solving and reason-based mathematics as well as institutionalize procedures of IKS selection, contextualization, and instruction (Madlela, 2024; Shabalala et al., 2025). It is

impossible to implement the government policy without such alignment in the hands of teachers in existing accountability pressure.

4.3.2 Professional Development

The learning process of teachers should not remain focused on the compliance-based models but rather adopt the participatory, inquiry-oriented, and community-based approaches that enable the acquisition of epistemological confidence and the pedagogical competence in the usage of IKS (Ajani, 2025; Battiste, 2002). Professional development is effective when it is based on life-long learning through continuous interactions with indigenous knowledge holders, working with local communities, and studying indigenous approaches to mathematics, including spatial reasoning in cultural objects, indigenous systems of measurement, and patterning in crafts, connected with formal curriculum results (Aikenhead & Michell, 2011; Madlela, 2022). Studies indicate that when teachers are involved in curriculum co-design using indigenous knowledge, they gain better knowledge and the classroom integration becomes more authentic (de Beer & Van Wyk, 2012; Ogunniyi, 2011). Colleges and universities play a pivotal role in redesigning pre-service and in-service teacher education to help instill indigenous epistemologies as a central curriculum that will provide teachers with the capacity to practice the IKS pedagogy (Opoku & James, 2021).

4.3.3 Teacher involvement in Curriculum Co-Creation

Teachers need to be restructured as co-creators of curriculum reform and not as peripheral implementers. The Triple Helix illustrates that government, academia, and teacher agency relationships are best based on co-evolutionary relationships and not top-down flows (Etzkowitz & Leydesdorff, 2000; Cai & Etzkowitz, 2020). Institutionalized meaningful teacher involvement can take place through formal mechanisms, including structured curriculum decision-making roles, school-university research collaborations, or community-based curriculum hubs (OECD, 2025; Priestley et al., 2012). Quadruple Helix approach emphasizes that the indigenous knowledge holders and other local organizations are critical co-design partners to enhance cultural authenticity and relevance (Hossain et al., 2023; Shyiramunda & van den Bersselaar, 2024).

4.3.4 Consequences of IKS related to Lack of Action

In the absence of substantive IKS integration, there would be continuation of Western epistemic dominance, the alienation of knowledge of the learner, the lack of engagement, and the continuation of epistemic injustice (Vandeyar, 2020; Khupe, 2020). The stakes go beyond pedagogy to the educational rights of the learners and constitutional obligations of South Africa to equity, dignity, and cultural recognition.

5. Contribution of the Study

5.1 The Post-Apartheid Context and the Urgent Need for This Study

To be thoroughly appreciative of the contribution of this paper, it would be necessary to place it within the historical and current context of post-apartheid South African

education curriculum reform, in which the process of curriculum reform has overtones of social justice, epistemic rights, and democratic transformation. During apartheid, education was clearly structured as the means of racial and epistemic oppression. The policies, like the Bantu Education Act of 1953, specifically offered Black South Africans worse education and kept African knowledge systems, languages, and cultural practices out of the formal syllabus (Gumede & Biyase, 2016; Jansen & Taylor, 2003). This heritage institutionalized the Western epistemological systems as the knowledge paradigm to be used in academics and rejected indigenous African knowledge as pre-scientific, superstitious, or irrelevant.

Following the democratic transition in 1994, the first series of curriculum reform cycles began to break this legacy and modernize education in line with constitutional principles of equity, dignity, and cultural recognition. Outcomes-based education presented in the curriculum 2005 through learner-based and culturally relevant objectives was implemented with challenges in terms of insufficient preparation of teachers, insufficient resources, and bureaucracy (Hoadley, 2017). Other reforms, such as the Revised National Curriculum Statement and Curriculum and Assessment Policy Statements (CAPS) of 2011, attempted to define content and lessen teacher workload.

Nevertheless, critics note that CAPS gives more preferences to formal knowledge structures at the expense of epistemological variety, returning to a content-driven reasoning (Molapo & Pillay, 2018). Although it has been reformed for three decades, there is evidence that the mathematics curriculum continues to be dominated by Western epistemologies. Indigenous Knowledge systems (IKS) inclusion has been shallow, disjointed, teacher-driven and has little system support to guarantee genuine integration in formal teaching and learning (Madlela, 2022; Onwu & Mosimege, 2004).

It is evident in this historical context that the issue of IKS integration in mathematics education is not only a technical problem of curriculum design, but a highly political and epistemological issue, which lies in unanswered questions of whose knowledge is counted in the post-apartheid state and how the curriculum can become transformed into a mechanism of epistemic exclusion to epistemic justice. This research is a part of this urgent discussion as it offers the first systematic theoretical investigation of IKS integration in mathematics education (as a Triple Helix framework) to expose the principles of power dynamics, structural imbalances, and teacher agency that interrelate to suggest whether curriculum reform hopes emerge into classroom realities.

5.2 Analytical and Theoretical Contributions

The paper has made some analytical and theoretical contributions to the research on mathematics curriculum reform, Indigenous Knowledge Systems (IKS), and teacher agency in post-apartheid South Africa. Using the Triple Helix model, it illustrates how power hierarchies and structural tensions between the government, institutions

of higher learning, and teachers' agencies determine the opportunities of IKS integration. The framework applies its already known applicability in the field of science and technology policy to culturally and humanistically informed educational change. Agency of mathematical teachers is re-conceptualised as an interactive, epistemic mediator, which presents teachers as active co-creators of knowledge, whose professional judgment, cultural knowledge, and pedagogical discretion are the determinants of how the IKS aspirations can be converted into meaningful classroom experiences. The combination of the Ecological Model of Teacher Agency and the Postcolonial Theory also elucidates the variation in teacher responses to the IKS integration in similar policy settings and how historical epistemic hierarchies restrict teacher power even in formally decolonizing curriculum frameworks.

Another point that has been made in the paper is that the policy-practice gap is created through structural misfit between curriculum policy, the design of assessment, and teacher professional development that limits culturally responsive IKS pedagogy. It promotes a responsive curriculum transformation paradigm that places teachers in the center of epistemic action, institutionalizes school-university-community alliances, and shows how the Triple Helix can result in epistemic justice and culturally significant learning. Such insights can offer a solid theoretical basis to policymakers, teacher educators, and curriculum designers who are determined to incorporate authentic IKS in South African mathematics education.

6. Conclusion

As presented in this paper, a meaningful introduction of Indigenous Knowledge Systems into formal curricula is not possible unless relationships between the main stakeholders in curriculum reform are reconfigured critically. Using the Triple Helix model, the discussion shows that the innovation in education is not only developed by the policy dictates or in the production of academic knowledge, but is a dynamic, mutual interaction of the government, higher education institutions, and teacher agencies. Nevertheless, in situations where such interactions are defined by hierarchical power relations in which policy and scholarly experience reign over the experiential and cultural wisdom of teachers, curriculum reform initiatives can lead to epistemic exclusion instead of enacting change.

Teacher agency is a force which is important in the nexus. Teachers do not simply follow the curriculum but are active interpreters and innovators whose professional judgment will influence the process of knowledge selection, contextualization, and implementation in the classroom. On the other hand, teachers who are given professional freedom, professional room and place and recognized as epistemic beings are in better positions to mediate between formal curriculum information and the indigenous and local practices of knowing in pedagogically genuine manners. Secondly, the effective implementation of IKS needs to be accompanied by a change in policy-based compliance into practice-based curriculum transformation, based on social justice, epistemic plurality, and contextual relevance. A responsive curriculum reform approach will then need to institutionalize teacher agency in the Triple Helix,

encourage long-term, cross-sector collaboration, and appreciate indigenous knowledge as a living, dynamic resource as opposed to a curriculum-based addition.

7. Recommendations

The analysis presented in this paper generates a coherent and integrated set of recommendations for transforming the Triple Helix of curriculum reform in South African mathematics education into a genuinely responsive system capable of supporting authentic IKS integration. These recommendations are interconnected, each reinforcing the others, and must be understood as components of a systemic reform agenda rather than isolated corrective measures. The foundation of this agenda is the formal institutionalization of teacher agency within the curriculum reform system. Teacher agencies and practicing mathematics teachers must be included in national and provincial curriculum decision-making bodies as substantive epistemic partners, not merely consultative voices, ensuring that curriculum policy is grounded in classroom realities and genuine pedagogical knowledge (OECD, 2025; Priestley et al., 2012).

This structural repositioning of teachers is inseparable from the need to redesign teacher professional learning around community-based, reflective, and indigenous-centered pedagogies that equip teachers with the epistemological competence and pedagogical resources to integrate IKS in mathematically meaningful and culturally authentic ways (Ajani, 2025; Battiste, 2002; Madlela, 2022). Such professional learning cannot function in isolation from broader structural reforms; consequently, governments must work with higher education institutions to establish sustained collaborative platforms, including joint curriculum development hubs, school-university research partnerships, and policy-practice forums – that transform the knowledge flow within the Triple Helix from hierarchical to genuinely collaborative and co-evolutionary (Cai & Etzkowitz, 2020; Hossain et al., 2023).

Underpinning all of these collaborative efforts must be coherence among curriculum frameworks, assessment systems, and teacher education policy. As long as assessment regimes continue to privilege standardized forms of mathematical representation that are epistemologically misaligned with IKS, teachers will face structural contradictions that limit the depth and authenticity of their IKS integration regardless of their professional commitment or preparation (Hoadley, 2017; Tariq, 2025). Finally, educational institutions must provide the recognition, support, and funding for teacher-led curriculum experimentation that positions teachers as co-producers of educational knowledge – acknowledging that the most contextually valid curriculum innovations in diverse South African school settings are likely to emerge from the professional wisdom of teachers who are deeply embedded in their communities and who understand, from lived experience, how indigenous mathematical knowledge intersects with the formal curriculum in pedagogically generative ways.

Conflict of Interest

The authors declare that there is no conflict of interest.

8. Acknowledgements

The authors extend their gratitude to their university, the University of South Africa, for providing them with the opportunity to conduct this research work. Furthermore, Quillbot and Grammarly were utilized in the process of writing this paper. It was merely applied to improve grammar and paraphrasing, respectively. Nonetheless, this paper is an embodiment of the original work of the authors.

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