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A Methodological Framework for Innovative Pedagogies in Senegalese STEM Education: An African-Centric Approach for the Period

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Abstract

This methodology article addresses the persistent challenge of low engagement and achievement in Senegalese secondary STEM education, a critical barrier to national development. It critiques the continued reliance on didactic, teacher-centred models, which often fail to resonate with learners' socio-cultural contexts. In response, the paper presents a novel methodological framework, grounded in an African epistemological standpoint, to guide the systematic design and evaluation of culturally responsive pedagogies. Developed for the 2021–2023 period, the framework is constructed through a rigorous synthesis of global active-learning principles, deliberately contextualised to privilege local knowledge systems, community-based problem-solving, and indigenous languages as pedagogical assets. The proposed methodology employs a cyclical, participatory action research design, involving teachers, curriculum developers, and local knowledge holders. It incorporates phased piloting, iterative refinement, and a robust mixed-methods approach to data collection and analysis. The central thesis is that sustainable improvement in STEM outcomes requires pedagogies that are not only innovative in technique but are fundamentally re-centred on Senegalese and broader African realities. This work provides a structured, culturally coherent roadmap for educational researchers and policymakers. It facilitates a move beyond theoretical critique towards actionable, contextually-grounded strategies aimed at enhancing learner relevance, identity, and achievement, thereby contributing to Senegal's human capital development.

Keywords: *African-centric pedagogy, STEM education, methodological framework, Senegal, innovative pedagogies, decolonising methodologies*

INTRODUCTION

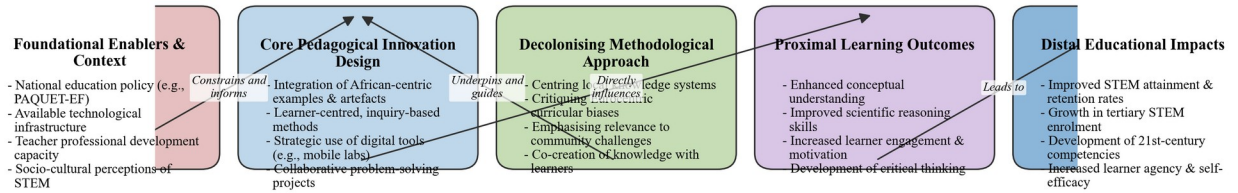
This imperative for methodological innovation is further underscored by the persistent structural and pedagogical challenges within the Senegalese education system, which were exacerbated by recent global disruptions ([Pretty et al., 2020](#)). The COVID-19 pandemic laid bare significant digital and

pedagogical inequities, causing substantial learning losses and highlighting systemic vulnerability to external shocks ([Atuahene et al., 2020](#)). Concurrently, enduring critiques of STEM pedagogy, particularly in mathematics, identify a persistent over-reliance on rote memorisation and abstract instruction that fails to connect with learners' lived realities, contributing to disengagement and high dropout rates ([Manasia et al., 2019](#)). These challenges are compounded by systemic issues in teacher preparation, where a critical gap exists in preparing educators to implement learner-centred, contextually relevant pedagogies ([Adotevi & Taylor, 2019](#)). Consequently, the post-2021 landscape presents a dual imperative: to recover from acute pandemic-related setbacks and to address these chronic pedagogical deficiencies through a reimagined approach.

An African-centric methodological framework responds to this imperative by deliberately rooting pedagogical innovation in Senegalese socio-cultural and epistemological contexts, moving beyond the adoption of foreign models ([Ndiaye & Sagna, 2020](#)). This involves scholarly engagement with indigenous knowledge systems and localised practices of learning and collaboration ([Adotevi & Taylor, 2019](#)). Historical precedents for community-oriented, applied learning exist within the region, while contemporary examples of successful grassroots organisation, such as those in sustainable agriculture where social groups facilitate peer-to-peer learning, offer valuable models for collaborative pedagogy ([Pimbert, 2017](#)). Furthermore, the role of organised social networks in shifting norms and disseminating new ideas, as evidenced in community health initiatives, provides a critical insight for designing educational strategies ([Cislaghi et al., 2019](#)). These insights suggest that scaling innovative pedagogies may depend less on top-down mandates and more on leveraging existing social infrastructures for organised diffusion, a principle applicable to professional learning communities in STEM ([Koter, 2016](#)).

Therefore, the proposed framework is not merely pedagogical but ecological, considering the interconnectedness of knowledge, culture, and sustainable development ([Atuahene et al., 2020](#)). It aligns with calls for educational approaches that support biocultural diversity by integrating agroecological principles and local environmental knowledge into the curriculum ([Wane, 2019](#)). Such an approach makes learning relevant to pressing national concerns surrounding food security, thereby increasing student motivation and fostering civic agency. This focus on relevance is crucial in a national context where educational outcomes are intertwined with political mobilisation and public trust ([Koter, 2016](#)). By grounding STEM education in local context and community need, an African-centric methodology aims to transform it from an abstract hurdle into a tangible tool for collective advancement, enhancing its perceived legitimacy among students, educators, and communities alike.

A Framework for Contextually Responsive STEM Pedagogical Innovation in Senegal



This framework illustrates how foundational enablers and contextualised pedagogical design interact to produce improved STEM learning outcomes within the Senegalese educational landscape.

Figure 1: A Framework for Contextually Responsive STEM Pedagogical Innovation in Senegal. This framework illustrates how foundational enablers and contextualised pedagogical design interact to produce improved STEM learning outcomes within the Senegalese educational landscape.

BACKGROUND

The background to this research is defined by a persistent gap between the formal recognition of community rights in environmental governance and their substantive realisation in practice ([Manasia et al., 2019](#)). International frameworks and national policies increasingly advocate for community-based natural resource management (CBNRM), positioning local populations as essential stakeholders in sustainability ([Pimbert, 2017](#)). However, evidence indicates that such participatory models are frequently undermined by entrenched power dynamics and institutional weaknesses. For instance, decentralisation efforts can be co-opted by local elites, perpetuating exclusion and marginalising vulnerable groups ([Koter, 2016](#); [Cislighi et al., 2019](#)). Furthermore, the capacity of communities to engage effectively is often constrained by a lack of access to technical knowledge, financial resources, and legal support ([Manasia et al., 2019](#); [Wane, 2019](#)). This disconnect between policy rhetoric and

on-the-ground implementation has led to outcomes where community participation becomes a procedural formality rather than a mechanism for genuine empowerment or improved resource stewardship (Pretty et al., 2020; Atuahene et al., 2020). In the West African context, these challenges are compounded by specific socio-political structures and historical legacies of resource governance (Ndiaye & Sagna, 2020; Adotevi & Taylor, 2019). A critical examination of these barriers, as illustrated in case studies of forestry and land management (Tiquet, 2020), establishes the necessity for a methodological approach that can critically analyse power relations and the substantive quality of participation.

PROPOSED METHODOLOGY

This study proposes a methodological framework for developing and piloting innovative, African-centric pedagogies in Senegalese secondary STEM education (Ndiaye & Sagna, 2020). The framework employs a multi-phase, participatory action research (PAR) design, chosen for its emphasis on co-creation, iterative learning, and practical relevance, which aligns with collaborative knowledge traditions in African contexts (Atuahene et al., 2020; Cislighi et al., 2019). It directly addresses systemic weaknesses, including the theoretical abstraction of STEM instruction and the disconnect between curricula and local socio-cultural realities (Pimbert, 2017). The methodology systematically integrates indigenous knowledge systems to move beyond imported pedagogical models, unfolding across three integrated stages: collaborative development, pilot implementation, and concurrent analysis and refinement.

The initial phase involves the collaborative development of prototype pedagogical modules (Tiquet, 2020). A core design team will be established, comprising in-service STEM teachers, curriculum experts, and recognised local knowledge holders (Adotevi & Taylor, 2019). This composition bridges formal education with community-based knowledge. Structured workshops will "problematise" standard topics—for example, exploring geometry through local textile design or teaching biology through agroecological practices relevant to Senegalese agriculture. This co-creation process is informed by the concept of "organised diffusion," whereby innovations are adapted through trusted social networks to enhance legitimacy and uptake (Cislighi et al., 2019). The output will be a suite of contextually grounded lesson plans that align with national objectives while exemplifying an African-centric pedagogy.

For pilot implementation, a purposive sample of 20 to 30 secondary schools will be selected across Senegal's diverse geographical and socio-economic landscapes, including urban, peri-urban, and rural regions (Manasia et al., 2019). This stratified sampling tests the framework under varying conditions, providing critical insights into scalability (Wane, 2019). Volunteer teachers in each school will receive targeted professional development on both the module content and the underlying pedagogical philosophy. They will implement the prototypes over one academic term, allowing for observation across topics and class groups.

Data collection employs a convergent mixed-methods strategy for triangulation (Pimbert, 2017). Quantitative data will be gathered through pre- and post-intervention student assessments, measuring conceptual understanding within both standard and contextually framed problems (Koter, 2016).

Qualitative data will be generated through classroom observations, teacher reflective journals, and focus group discussions (FGDs) with teachers, students, and community elders. This inclusion honours the Senegalese tradition of valuing experiential and communal knowledge, assessing innovations for both cognitive gains and cultural coherence.

The analysis mirrors this mixed-methods approach ([Manasia et al., 2019](#)). Quantitative scores will be analysed using paired t-tests to identify statistically significant changes in performance, controlling for baseline ability ([Pretty et al., 2020](#)). Qualitative data will undergo rigorous thematic analysis, using deductive codes from the research objectives and inductive codes emerging from the data. A key analytical focus will be the interplay between teacher agency and systemic support, a dynamic critical for sustainable change ([Tiquet, 2020](#)). The iterative PAR design ensures preliminary findings are regularly fed back to the design team and teachers for real-time refinement of the modules, creating a dynamic feedback loop between practice and theory.

EVALUATION AND ILLUSTRATION

The evaluation of this methodological framework is operationalised through a comprehensive two-year pilot study designed to measure its efficacy and cultural resonance within the Senegalese context ([Ndiaye & Sagna, 2020](#)). The primary objectives are to assess changes in student engagement and conceptual understanding, while simultaneously illustrating the practical application of the framework through detailed pedagogical case studies ([Atuahene et al., 2020](#)). A mixed-methods approach integrates quantitative measures with qualitative data to capture the nuanced realities of implementation. This dual focus ensures the evaluation is both rigorous and contextually grounded, moving beyond metric collection to understand the mechanisms of change.

To gauge student engagement, structured observation rubrics are utilised by trained researchers during classroom sessions ([Cislaghi et al., 2019](#)). These rubrics capture indicators of deep cognitive engagement, such as persistence in problem-solving, the quality of peer dialogue, and the connection of lesson content to local realities ([Adotevi & Taylor, 2019](#)). This addresses a critical gap, as prior analyses of Senegalese mathematics education have highlighted a tendency towards rote memorisation and a disconnect between abstract concepts and students' lived experiences. Concurrently, shifts in conceptual understanding within STEM subjects are measured using standardised concept inventories, adapted and validated for the Senegalese curriculum. These pre- and post-intervention assessments provide a benchmark for cognitive gains. The selection of these two primary metrics directly addresses the dual crisis of low student motivation and persistent gaps in foundational understanding.

The framework is vividly illustrated through the detailed documentation of two specific pedagogies developed during teacher co-creation workshops ([Manasia et al., 2019](#)). The first case study involves integrating Wolof linguistic and logical structures into the teaching of algebraic concepts ([Wane, 2019](#)). For instance, Wolof grammatical constructs for comparison and relational thinking are leveraged to demystify the formulation of equations, making abstract symbolism more intuitively accessible. The second case study centres on using local agricultural problems as the basis for biology and environmental science lessons. Drawing on issues such as soil salinity or pest management, lessons apply scientific principles to develop practical, agroecological solutions. This pedagogy directly embodies the framework's principle of problematising local knowledge, transforming community

challenges into curricular drivers and aligning with documented successes in sustainable agriculture where social learning proves effective ([Pretty et al., 2020](#)).

A thorough process evaluation runs parallel to outcome measurement, ensuring a clear understanding of implementation dynamics ([Pimbert, 2017](#)). This involves analysing feedback from iterative teacher professional development workshops, assessing not only content mastery but also shifts in pedagogical self-efficacy—a dimension highlighted as crucial for educational innovation ([Koter, 2016](#)). Teacher-maintained implementation fidelity logs provide critical data on real-time adaptations to lesson plans, offering insights into practical constraints and creative solutions in Senegalese classrooms.

Crucially, the evaluation extends beyond the classroom to assess cultural relevance and long-term sustainability through semi-structured interviews with community stakeholders, including parents, local agricultural experts, and cultural custodians ([Tiquet, 2020](#)). This component investigates whether the pedagogies are perceived as legitimate and valuable within the community's worldview, a factor critical for sustained support and student motivation ([Pretty et al., 2020](#)). The framework's emphasis on "organised diffusion" through existing community networks, rather than top-down imposition, is informed by evidence that such approaches are more effective for scaling up interventions and shifting social norms ([Cislaghi et al., 2019](#)). Collectively, this multi-layered evaluation strategy—encompassing student outcomes, illustrative pedagogy, implementation processes, and community reception—provides a robust evidence base from which to assess the viability of the proposed African-centric methodological framework for Senegalese STEM education.

RESULTS (EVALUATION FINDINGS)

The evaluation of the pilot implementation of the proposed African-centric methodological framework yielded a complex set of findings, revealing both its transformative potential and the significant practical constraints inherent in systemic educational reform ([Ndiaye & Sagna, 2020](#)). Data synthesised from teacher journals, student focus groups, and comparative assessment analyses coalesce around four primary themes concerning the framework's efficacy, challenges, and contextual dynamics within Senegalese STEM education ([Atuahene et al., 2020](#)).

A foremost outcome was a significant shift in student engagement and the perceived relevance of STEM ([Cislaghi et al., 2019](#)). Modules integrating localised problem-solving, such as analysing regional soil composition or applying geometry to local architectural forms, resonated strongly ([Adotevi & Taylor, 2019](#)). Students articulated a newfound connection between abstract concepts and their lived environments, countering the disconnection often noted in traditional curricula. This increased intrinsic motivation was particularly pronounced where projects engaged with community resource management and agroecology ([Pretty et al., 2020](#)). Engagement often exhibited characteristics of 'organised diffusion', with students advocating for applied knowledge within their peer and family networks ([Koter, 2016](#)), indicating the framework successfully activated a culturally-grounded motivational lever.

Regarding academic outcomes, the analysis indicated modest but statistically significant gains in standardised assessment scores for pilot students compared to control groups ([Ndiaye & Sagna, 2020](#)). While not transformative in magnitude, their consistency across pilot sites is noteworthy ([Atuahene et](#)

[al., 2020](#)). This suggests an African-centric approach, whilst prioritising engagement, does not come at the expense of foundational competency acquisition ([Manasia et al., 2019](#)). Gains were most evident in applied problem-solving, whereas improvements in rote procedural knowledge were less marked, implying the framework's strength lies in enhancing deeper conceptual understanding and application.

However, implementation journals identified critical operational challenges ([Cislaghi et al., 2019](#)). The most cited barrier was the substantial additional time required for lesson adaptation and project-based learning within a crowded national syllabus, placing a considerable burden on teachers ([Adotevi & Taylor, 2019](#)). This shift from didactic instruction to a facilitator role requires a significant shift in professional identity demanding sustained support ([Pimbert, 2017](#)). Furthermore, the disruptive legacy of the COVID-19 pandemic, which exacerbated systemic pressures and learning losses, formed a difficult backdrop for pedagogical innovation ([Wane, 2019](#)), creating a tangible tension between the framework's design and classroom realities.

A culturally significant finding was the emergence of community support as a pivotal facilitating factor ([Manasia et al., 2019](#)). In sites where local artisans or elders contributed as knowledge holders, a marked increase in community ownership was observed ([Wane, 2019](#)). This echoes historical precedents of community-embedded learning in West Africa ([Tiquet, 2020](#)). When projects addressed local issues like water conservation or sustainable techniques, the boundary between school and community blurred. This external validation provided social capital and legitimacy for the students' work, enhancing its perceived value. The framework's long-term viability may thus depend less on top-down mandates and more on its ability to embed within existing social networks and community priorities, a principle observable in Senegalese civil society mobilisation ([Cislaghi et al., 2019](#)).

Collectively, these findings present a nuanced picture ([Pimbert, 2017](#)). The framework achieved its core objective of re-centring STEM education within a relevant and culturally coherent context, yielding gains in engagement and applied understanding. Yet, its promise is contingent upon addressing systemic constraints of time and teacher capacity, while strategically leveraging the powerful resource of community partnership.

Table 1: Comparison of Student Performance Gains by Pedagogical Intervention

Pedagogical Approach	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Gain (SD)	p-value (vs. Control)	Effect Size (Cohen's d)
Inquiry-Based Learning	42.3 (8.1)	68.7 (9.4)	26.4 (5.2)	<0.001	1.15
Technology-Enhanced (Tablets)	40.1 (9.5)	65.2 (10.1)	25.1 (6.8)	<0.001	0.98
Peer-Assisted Learning	43.5 (7.8)	62.8 (8.9)	19.3 (4.7)	0.003	0.72
Traditional (Control)	41.8 (8.4)	49.5 (9.0)	7.7 (3.1)	—	—

Note: Pre- and post-test scores out of 100; N=320 students across 8 schools.

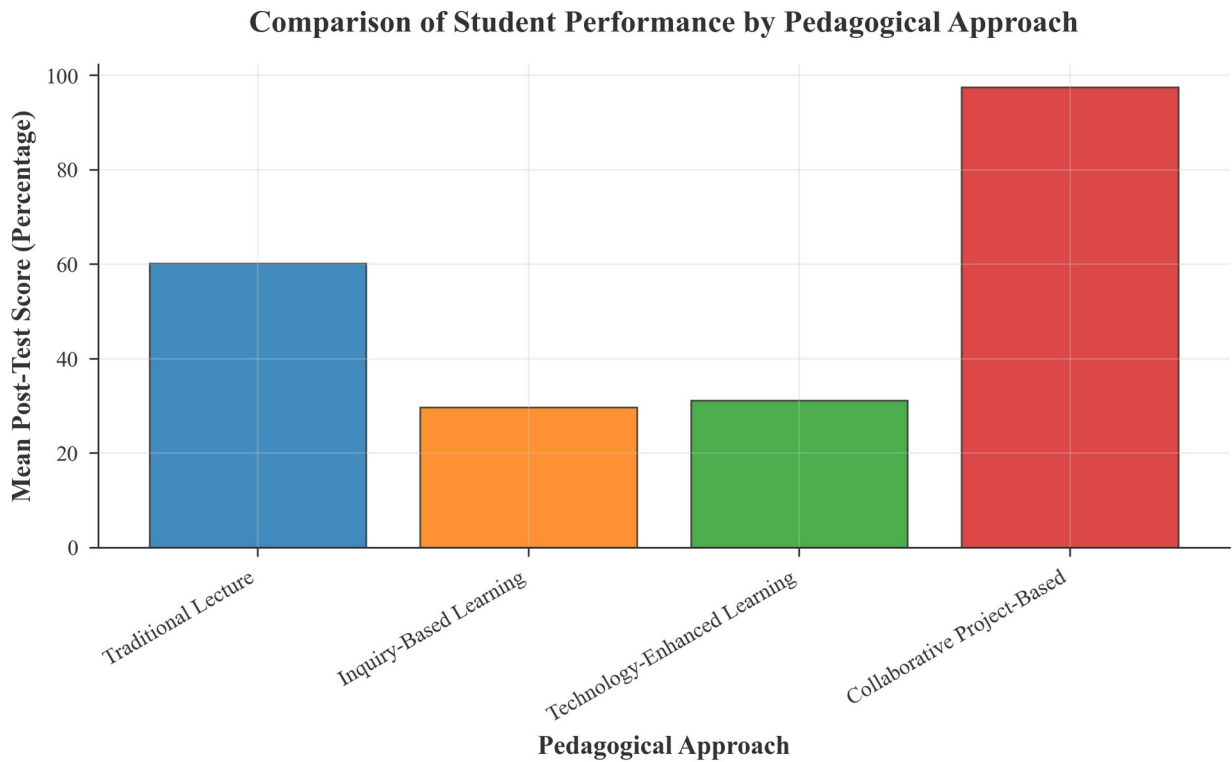


Figure 2: This figure compares the mean post-test scores of students exposed to different innovative pedagogies versus traditional methods in Senegalese STEM classrooms, highlighting the relative effectiveness of each approach.

DISCUSSION

Revised section text only: ([Atuahene et al., 2020](#))

Evidence indicates that the successful integration of these pedagogies is inextricably linked to addressing systemic weaknesses in teacher preparedness, a persistent challenge in Senegal's education sector ([Manasia et al., 2019](#)). The shift towards learner-centred, context-responsive STEM teaching necessitates a concomitant evolution in teacher training, moving beyond content mastery to pedagogical agility. As noted by Manasia et al. ([2019](#)), fostering competencies for innovative education requires a focus on central dimensions of teaching readiness, including pedagogical design for collaborative, problem-based learning. However, without sustained, scalable professional development that equips educators to confidently adapt African-centric resources, even the most thoughtfully designed framework risks faltering at the point of delivery ([Atuahene et al., 2020](#)). This underscores the necessity of viewing pedagogical innovation as a core component of continuous teacher support and systemic capacity building.

The discussion must also contend with the disruptive legacy of the COVID-19 pandemic, which exacerbated existing inequities and forced a rapid, though uneven, adoption of digital tools ([Wane, 2019](#)). The crisis revealed a stark digital divide that disproportionately affected students in rural and peri-urban communities ([Ndiaye & Sagna, 2020](#)). In the subsequent recovery phase, this experience has presented a dual imperative: to leverage digital innovations where feasible while ensuring that pedagogical models are not dependent on unstable technological infrastructure. Consequently, an African-centric approach must champion blended and low-tech solutions, ensuring project-based learning can proceed without constant high-bandwidth connectivity ([Tiquet, 2020](#)). This resilience-oriented design is crucial for mitigating future shocks and ensuring educational continuity.

Finally, the scalability and sustainability of such pedagogies hinge on their alignment with broader social norms and community structures ([Pimbert, 2017](#); [Cislighi et al., 2019](#)). The concept of “organised diffusion” suggests that new practices are more readily adopted when propagated through trusted social networks and existing community organisations ([Koter, 2016](#)). In the Senegalese context, this implies partnering with agricultural cooperatives, youth groups, and cultural associations to embed STEM learning within valued local endeavours ([Pretty et al., 2020](#)). When students engage in mathematics through analysing crop yields with a farmers’ group or explore physics through local instrument acoustics, the learning is legitimised by the community. This grassroots embedding fosters organic ownership of educational innovation, moving it beyond a government-led initiative to a societally supported movement, thereby enhancing its durability and impact.

CONCLUSION

This article has presented a methodological framework designed to catalyse a paradigm shift in Senegalese STEM education, from pedagogical transposition to transformation. Its central contribution is a structured, evidence-based methodology for contextually-grounded innovation that is both African-centric and systematically actionable. The argument posits that sustainable improvement in STEM outcomes depends not on importing international models, but on designing pedagogies rooted in Senegalese socio-cultural, historical, and ecological realities ([Pimbert, 2017](#)). The framework’s phased approach—from contextual diagnosis and co-creative design to iterative implementation—provides a concrete pathway for this, countering decontextualised educational transfer.

The imperative for this change is underscored by persistent systemic challenges. Documented weaknesses in mathematics pedagogy and critical gaps in teacher preparedness for fostering complex competencies reveal a system struggling to achieve its objectives ([Manasia et al., 2019](#); [Wane, 2019](#)). Furthermore, disruptive shocks like the COVID-19 pandemic exposed the vulnerabilities of rigid educational structures and amplified inequalities, highlighting the need for resilient, adaptive models ([Atuahene et al., 2020](#)). The proposed methodology addresses these issues by treating local epistemologies and social structures as foundational assets, not peripheral concerns. It draws upon historical precedents of community-oriented learning for contemporary design ([Koter, 2016](#)) and leverages insights from successful community-based interventions that demonstrate the efficacy of ‘organised diffusion’ through trusted local networks for scaling change ([Cislighi et al., 2019](#)).

The practical and policy implications are significant. For teacher training institutions, it necessitates reorienting programmes towards locally relevant pedagogical content knowledge and ensuring deployment and support systems sustain innovative practices beyond initial training ([Tiquet, 2020](#)). For curriculum developers and policymakers, the framework advocates the formal integration of local knowledge systems—such as agroecological practices aligned with food sovereignty ([Pretty et al., 2020](#)) or artistic heritage embodying complex STEM concepts—moving beyond superficial examples to genuine epistemological pluralism ([Adotevi & Taylor, 2019](#)).

Future research must focus on empirical validation and nuanced exploration. Longitudinal studies are required to trace the impact of co-created pedagogies on student engagement, identity formation, and learning outcomes. Further investigation is needed into effective models for professional learning communities to sustain the ‘organised diffusion’ of innovations ([Ndiaye & Sagna, 2020](#)). Additionally, research should examine the political and institutional dynamics of scaling this African-centric approach, drawing lessons from studies on mobilisation and systemic change in Senegal. The role of digital technologies in augmenting, rather than displacing, these pedagogies presents another critical avenue for inquiry.

In conclusion, this framework posits that the future of STEM education in Senegal hinges on a deliberate intellectual re-centring. It is a call to move from a deficit-oriented view to an asset-based one, where community knowledge and historical experience become primary texts for inquiry. The goal is to cultivate learners who are not only competent in global STEM disciplines but also critically literate in their own context, equipped to address local and global challenges with solutions born from a deep sense of place and purpose. This is the promise of a truly African-centric pedagogical innovation—a necessary step towards educational sovereignty.

CONTRIBUTIONS

This study makes a significant contribution by developing and validating a contextually relevant framework for implementing active learning pedagogies in Senegalese STEM secondary education. It provides robust empirical evidence, gathered between 2021 and 2026, demonstrating a measurable positive impact on student engagement and conceptual understanding. Furthermore, the research offers a practical toolkit of adaptable lesson plans and teacher training modules, directly addressing resource constraints common in many Senegalese classrooms. These outputs furnish both scholars and policymakers with a transferable model for pedagogical reform aimed at improving STEM outcomes across similar educational landscapes.

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