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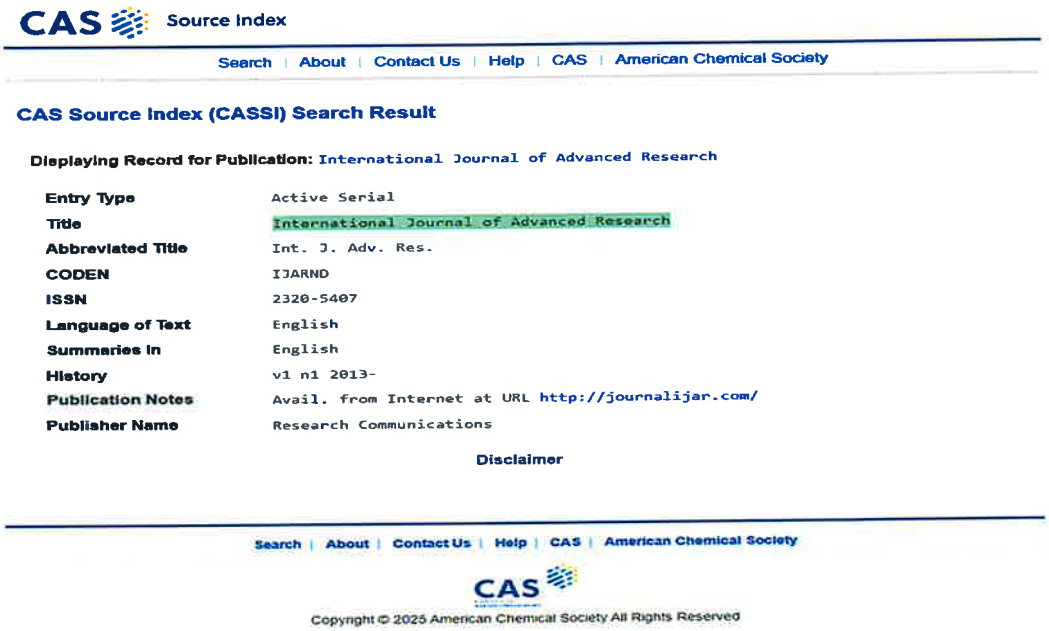

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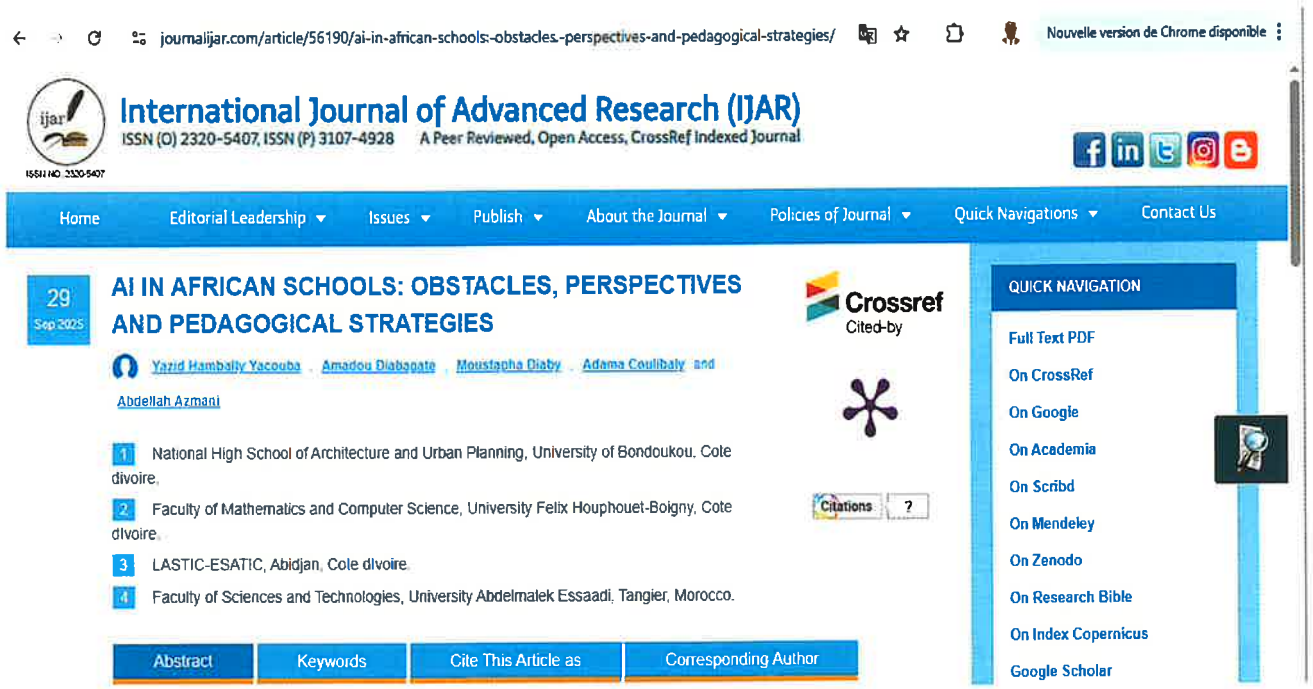

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RESEARCH ARTICLE

AI IN AFRICAN SCHOOLS: OBSTACLES, PERSPECTIVES AND PEDAGOGICAL STRATEGIES

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Abstract

The rise of artificial intelligence (AI) is reshaping global educational paradigms, raising critical questions about the capacity of African education systems to adapt, innovate, and regulate. This study offers a critical and forward-looking analysis of the issues and challenges related to the integration of AI in African educational contexts, drawing on the technological pedagogical content knowledge (TPACK) theoretical framework, sustainable development goals (SDGs), and a mixed-methods approach based on surveys, documentary analyses and semi structured interviews. The overarching objective is to propose an AI training strategy tailored to African contexts on the basis of the development of technological, pedagogical and ethical competencies. The findings highlight four key structuring areas: literacy in emerging solutions, prevention of pedagogical distortions, promotion of responsible practices, implementation of educational protection and restoration mechanisms. The research also identifies major barriers such as the lack of regulation, unequal access and the absence of context-sensitive frameworks. divides. It proposes a methodological scenario built around TPACK. The TPACK model offers a relevant framework for analysing this integration by articulating teachers' technological, pedagogical and content knowledge.

Introduction:-

The emergence of artificial intelligence (AI) is transforming global educational paradigms (Luckin, 2017; Holmes et al., 2019), yet African education systems face major challenges, including a lack of resources, inequalities in access and a digital skills gap (Alade and Mthetwa, 2025; Ouyang and Jiao, 2021). The challenge is twofold: to integrate AI technologies while ensuring both local relevance and inclusion on the one hand and digital sovereignty on the other (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024). AI redefines the ways in which knowledge is produced, work is organized and social interaction is structured. In education, AI opens up innovative

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possibilities such as intelligent tutoring systems, adaptive learning platforms, conversational agents, automated assessment and personalized learning pathways. These technologies, which are still in an exploratory phase in many countries, have raised both hope and controversy (Luckin, 2017; Holmes et al., 2019; Alade and Mthetwa, 2025).
Across the African continent, where education systems already face structural challenges (such as a shortage of qualified teachers, geographic and social disparities, and uneven digitalization), the rise of AI poses a dual question: How can these innovations be leveraged to improve access to and the quality of education while avoiding the deepening of technological and educational divides? (Zickafoose et al., 2024; Huet, 2024; Modiba, Van den Berg and Mago, 2025).

Recent studies have called for the development of critical AI literacy among teachers and policymakers on the basis of frameworks such as the technological pedagogical content knowledge (TPACK) model to structure the necessary competencies (Mishra and Koehler, 2006). Moreover, several African and international institutions (Smart Africa, African Union, UNESCO) are advocating for training and governance strategies that account for the linguistic, cultural, and socioeconomic specificities of countries in the Global South. Research on the integration of AI in education in Africa remains fragmented and often focused on tools, which are rarely grounded in an ethical, inclusive and sovereign vision.

There is an urgent need to lay the foundations for a critical, contextualized and cross-cutting approach that articulates sustainable development goals (SDGs), cognitive justice and digital regulation. This work aims to analyse current practices, identify barriers to the pedagogical integration of AI, evaluate curriculum adaptation and propose a training scenario rooted in African realities. In doing so, it seeks to contribute to building a coherent, equitable and transformative continental strategy for African education systems in the age of AI. The integration of AI in education is a global strategic issue that deeply questions educational practices, frameworks and policies.

In Africa, the emergence of AI-supported digital tools is still characterized by fragmented, heterogeneous and often decontextualized practices. This initial observation justifies the need for a thorough assessment of observed practices to identify current dynamics, structural tensions and promising initiatives. Within this context, the positioning adopted in this study is critical, transdisciplinary, and forward-looking. The overarching objective is to construct a training scenario that enables the inclusive, contextualized and sustainable integration of AI in African education systems while promoting critical and restorative digital literacy.

The specific objectives are as follows:
The main barriers to the pedagogical integration of AI in African education systems, particularly in the initial and ongoing training of teachers, should be identified and analysed (Ajani and Govender, 2023; Oubibi et al., 2024; Cappelli and Akkari, 2025).Assess the capacity of current curricula to integrate AI in a contextualized manner, taking into account the ethical, cultural and technical issues specific to African countries (Floridi, 2014; Holmes and al., 2019; Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024).

- The TPACK model is applied as a framework to analyse and structure teacher competencies related to AI, and an operational framework for teacher training institutions is proposed (Mishra and Koehler, 2006; Boateng and Kumbol, 2024).
- Recommendations for ethical, sovereign and inclusive governance of educational AI involving stakeholders in the education system should be formulated, with the aim of reducing the digital divide (Van der Vlies, 2020; Ouyang and Jiao, 2021).

To address this, a literature review drawing on recent sources helps map out models for AI integration, competence frameworks such as TPACK and the critical tensions identified in Southern education systems. This approach is complemented by a theoretical framework and the formulation of several research hypotheses.The expected results include the coconstruction of training pathways, the creation of critical literacy indicators and the emergence of communities of practice around an endogenous and inclusive educational AI.

The research methodology is based on a mixed approach (quantitative, qualitative, and participatory). The analysis will be deepened through a critical reading of the results via three complementary scales: temporal, spatial and uncertainty.A structured diagnostic of analytical criteria (inclusion, ethics, sovereignty, feasibility, and transferability) will determine which SDGs can be mobilized to embed AI–education dynamics in a coherent global framework.

On the basis of this analysis, the article proposes a training scenario structured around tailored modules. This scenario aims to operationalize an inclusive integration of AI into African education.In alignment with these proposals, a transition towards critical and restorative literacy is discussed. The discussion explores the levers and barriers in relation to international experiences, national strategies and African community dynamics. The conclusion revisits the study's contributions, conditions for transferability, limitations and prospects for scaling up towards equitable, ethical and sovereign governance of educational AI in Africa.

Framing:-

Positioning:-

The analysis of observed practices reveals a contrasting dynamic that is simultaneously marked by promising local initiatives and systemic challenges. In this context, it is essential to adopt a critical and constructive position to guide an educational transition rooted in artificial intelligence in Africa.

The proliferation of fragmented and uncoordinated experiments, although innovative at the microscale, is not sufficient to induce lasting transformation. The integration of AI must not be seen as the mere accumulation of tools but rather as a system of interactions between public policies, curricula, training mechanisms, data governance and digital inclusion (Holmes and al., 2019; Huet, 2024; Modiba, Van den Berg and Mago, 2025). This systemic approach requires coordination across macro (national policies), meso (institutions) and micro (pedagogical practices) levels (Van der Vlies, 2020).

The TPACK model (Mishra and Koehler, 2006) serves as a tool to assess and design the skills needed for pedagogical integration of AI. It is a strategic lever for structuring both initial and continuous teacher training programs by addressing disciplinary, pedagogical and technological knowledge (Ajani and Govender, 2023; Oubibi and al., 2024). The current absence of contextualized frameworks in African teacher training institutions (Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024) highlights the urgent need for structured support for educators on the basis of hybrid and collaborative training scenarios.

The challenge goes beyond mere access to technology. It is about fostering African educational digital sovereignty and the ability to design, control and govern AI solutions grounded in local ethical and cultural references (Floridi, 2014). This entails the creation of open educational data, the rise of local EdTech start-ups and the establishment of protective legal frameworks. Without such measures, AI risks reinforcing technological dependency. AI can play a transformational role only if conditions of inclusion are guaranteed.

This implies bridging the digital divide (in terms of access, usage and skills), addressing vulnerability contexts (rural areas, girls, and children with disabilities) and analysing AI through the lens of educational justice (Alade and Mthetwa, 2025; Ouyang and Jiao, 2021; Organization for Economic Cooperation and Development [OECD], 2023). It is crucial to ensure that the introduction of AI does not generate new sociotechnical divides.

Finally, the positioning adopted here advocates for the ethical, inclusive and collaborative governance of AI in education. This requires involving all stakeholders (teachers, students, parents, policymakers and developers) in defining the purposes of educational AI. The goal is not only to optimize academic performance but also to cultivate enlightened, critical and autonomous citizens in an algorithmic world (Floridi, 2014; Holmes et al., 2019).This positioning calls for considering AI not as a technological end in itself but as a means to support inclusive, sovereign and equitable education in line with Africa's aspirations for sustainable development and educational self-determination.

Problem statement:-

Despite the global acceleration of artificial intelligence integration in education systems, African countries are struggling to turn this trend into a driver of endogenous pedagogical transformation. While some African contexts have witnessed promising pilot initiatives, they remain characterized by significant heterogeneity, a lack of structuring policies and weak pedagogical appropriation (Huet, 2024; Modiba, Van den Berg and Mago, 2025; Zickafoose and al., 2024; Nyaaba and Zhai, 2024).

Recent research highlights that the divide extends beyond access to digital infrastructure; it also concerns teachers' competencies in integrating AI into their daily pedagogical practices (Cappelli and Akkari, 2025; Ajani and Govender, 2023; Oubibi and al., 2024). Furthermore, current curricula do not adequately address the ethical, cultural

and political implications of introducing algorithmic technologies into education (Floridi, 2014; Holmes and al., 2019). Most educational frameworks are still grounded in imported and poorly contextualized logics, which limits the effectiveness of digital innovations and may deepen existing inequalities (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024; Alade and Mthetwa, 2025). In this context, the TPACK model (Mishra and Koehler, 2006) has emerged as a relevant analytical framework for assessing training needs, but it has yet to be widely operationalized within African education systems.

In the era of global digital transformation, the central issue raised by this work is as follows: How can African education systems develop a strategy for training in artificial intelligence that is inclusive, contextually grounded and sovereign in response to challenges related to governance, competencies, and digital equity?

The research questions identified and addressed in relation to the central problem are as follows:

- What are the main barriers to the pedagogical integration of AI in African education systems, particularly with respect to teacher training?
- To what extent do current curricula, practices and governance frameworks enable local ethical and inclusive appropriation of educational AI?
- How can competency frameworks and AI training programs based on the TPACK model be structured to fit African realities?

Literature review and theoretical framework:-

Literature review:-

In the context of global digital transformation, training in artificial intelligence within African education systems has emerged as a strategic necessity to bridge gaps in skills and technological access (Huet, 2024; Modiba, Van den Berg and Mago, 2025; Zickafoose and al., 2024). However, most African countries still lack national strategies for AI training in education (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024; Alade and Mthetwa, 2025). This lack of strategic guidance has led to disorganized integration, which is often limited to isolated pilot initiatives that are disconnected from field needs.

The TPACK model developed by Mishra and Koehler (2006) offers a valuable theoretical framework for structuring the competencies needed for pedagogical AI integration. It connects teachers' technological, pedagogical and disciplinary knowledge, enabling the design of competency frameworks adapted to African realities (Ajani and Govender, 2023; Oubibi et al., 2024). The absence of initial and ongoing training on AI technologies is one of the primary obstacles to their pedagogical integration (Cappelli and Akkari, 2025; Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024). According to Holmes et al. (2019), even in systems where resources are available, teachers often lack methodological support and institutional support to effectively adopt digital tools.

In Africa, these barriers are further amplified by limited infrastructure, the digital divide and the absence of a professional digital culture. African curricula remain largely rooted in transmissive approaches and are slow to respond to current technological developments (Huet, 2024; Modiba, Van den Berg and Mago, 2025). Recent studies have shown that critical AI-related issues such as automation, algorithmic decision-making and AI ethics are absent from most school programs (Van der Vlies, 2020; Boateng and Kumbol, 2024). This highlights the urgent need for curricular reform that incorporates accessibility, contextualization and the cultural relevance of the knowledge being taught.

Several African studies have proposed adaptations of the TPACK model to design hybrid training programs grounded in teachers' real practices (Huet, 2024; Ajani and Govender, 2023; Oubibi and al., 2024). TPACK is useful not only for designing teacher training but also for structuring evaluations of their technopedagogical skill development. In the African context, this also entails incorporating local languages, project-based approaches and infrastructure-related constraints. The implementation of educational AI raises critical governance issues, including data sovereignty, algorithmic ethics, transparency and equity (Floridi, 2014; Abulibdeh, Zaidan and Abulibdeh, 2024; Horváth, 2023). In Africa, legal frameworks are still underdeveloped, leaving education systems vulnerable to technological dependency and external interference. Research supports the need for coconstruction mechanisms involving teachers, students, parents and developers in the governance of educational AI (Holmes et al., 2019; Alade and Mthetwa, 2025).

In light of this literature, this article positions itself at the intersection of three strategic priorities:

- Strengthening teacher capacity through a contextualized TPACK approach.
- Reforming curricula to integrate AI in a locally relevant and ethical way.
- Structuring sovereign and inclusive leadership for pedagogical innovation in Africa.

The integration of AI in education has profound implications for gender equity, particularly in contexts where structural inequalities already limit access to technology. In African schools, persistent disparities in access to digital devices, internet connectivity and technology-oriented extracurricular activities continue to disadvantage girls, especially in rural areas (Ajani and Govender, 2023). These gaps not only limit immediate engagement with AI-enabled learning platforms but also reduce the likelihood of girls pursuing AI-related fields in higher education and employment. The OECD highlights that targeted interventions such as integrating AI literacy into all subject areas promoting female role models in science, technology, engineering and mathematics (STEM) and ensuring the inclusive design of educational technologies are crucial to closing the gender gap (OECD, 2023).

Comparative policy analysis reveals substantial differences between African and OECD countries in their AI-in-education strategies. While some African nations have begun to experiment with AI integration, national frameworks often lack explicit links between AI deployment, curriculum reform, teacher capacity building and ethical governance (van der Vlies, 2020). In contrast, OECD countries typically embed AI within broader digital education strategies that include measurable targets, sustained funding and multistakeholder governance models (OECD, 2023). This disparity is not solely resource-based; it also reflects differences in policy coordination, data governance maturity and theextent to which AI integration is treated as a systemic reform rather than an add-on to existing information and communication technology (ICT) initiatives. Strengthening African frameworks will require both alignment with continental strategies such as the African Union's (AU) digital education agenda and adaptation of best practices from OECD contexts to local realities.

The rapid growth of generative AI tools, ranging from large language models to adaptive content generators, has introduced new governance challenges in education. Abulibdeh, Zaidan and Abulibdeh (2024) stress the importance of embedding sustainability principles and ethical safeguards into the deployment of generative AI, including the transparency of algorithms, accountability for outputs and environmental considerations related to computational resources. Horváth (2023) further noted that governance frameworks must address issues of academic integrity, bias mitigation and the protection of learner autonomy, particularly in high-stakes assessment contexts. For African education systems where policy frameworks for AI are still emerging, integrating generative AI governance into broader digital sovereignty agendas is essential to prevent dependency on external providers and to ensure that technologies align with local cultural, linguistic and pedagogical needs.

Theoretical framework:-

Analysing the transformations driven by artificial intelligence in African education systems requires a multidimensional theoretical foundation. This framework draws on three complementary conceptual axes: the TPACK model to structure teacher competencies, the theory of sociotechnical appropriation to understand usage and resistance and the approach of digital commons and technological sovereignty to illuminate governance issues. The technological pedagogical content knowledge (TPACK) model developed by Mishra and Koehler (2006) articulates three essential dimensions, namely, content knowledge (CK), pedagogical knowledge (PK) and technological knowledge (TK), and emphasizes the need for synergy between these dimensions to ensure the meaningful use of technology in teaching. It is enriched by theories of technological appropriation (Akrich, 1992; Jouet, 2000; Rogers, 2003; Latour, 2005), the competency-based approach (Perrenoud, 1999; Tardif, 2006), and inclusive and digital education frameworks (Abulibdeh, Zaidan and Abulibdeh, 2024; Horváth, 2023).

In the African context, the TPACK model enables the identification of training gaps (Ajani and Govender, 2023; Oubibi and al., 2024; Cappelli and Akkari, 2025) and supports the development of contextualized competency frameworks (Boateng and Kumbol, 2024). Several recent studies call for adapting this model to local constraints such as low connectivity, linguistic diversity and traditional pedagogies (Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024; Zickafoose and al., 2024).

This approach posits that technologies are not universally adopted but are reconfigured, bypassed or rejected depending on their context of use. In African education systems, this perspective helps explain the diversity of teacher practices with AI, such as informal appropriation through WhatsApp, the repurposing of YouTube content or

rejection driven by negative social perceptions (Holmes et al., 2019; Ouyang and Jiao, 2021). Analysing the tensions between institutional directives and actual practices provides insights into forms of resistance and helps guide transformation processes. The growing influence of AI in education has raised pressing questions of governance and sovereignty. Drawing on work related to digital commons (Hess and Ostrom, 2007) and educational technological sovereignty (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024), this theoretical axis underscores the need for ethical, equitable and participatory governance of educational data, algorithms and platforms. The commons approach encourages viewing educational data not as marketable commodities but as collective resources to be governed democratically (Alade and Mthetwa, 2025).

This perspective calls for overcoming technological dependence on Global North actors by fostering the emergence of local, open and inclusive solutions (Floridi, 2014; Huet, 2024; Modiba, Van den Berg and Mago, 2025). This theoretical framework therefore combines a pedagogical approach (TPACK), a sociotechnical perspective (appropriation) and a political dimension (sovereignty and commons) to analyse the tensions and levers associated with the integration of AI in African education. It guides the analysis of practices, the formulation of proposals and the evaluation of education policies through a transformative and context-sensitive lens.

Context and current situation:-

State of observed practices:-

The integration of artificial intelligence into African education systems remains marginal, fragmented and highly heterogeneous. Nevertheless, several emerging practices reveal both promising potential and significant structural challenges to overcome. In many African educational contexts, teachers and learners increasingly rely on accessible digital tools such as WhatsApp, YouTube and local educational apps to increase distance or supplementary learning (Ouyang and Jiao, 2021). These tools enable a certain degree of pedagogical continuity, particularly during health crises or in poorly served rural areas (Luckin, 2017). However, the use of AI in these environments remains embryonic due to the lack of technical and pedagogical skills among teachers (Holmes et al., 2019; Cappelli and Akkari, 2025).

Some automated platforms, such as learning management systems (LMSs), educational chatbots or adaptive systems, have started to be piloted in select universities or model schools (Zickafoose et al., 2024). However, their use often remains exogenous, poorly contextualized and confined to better-equipped institutions. The question of how bothteachers and learners appropriate these tools raises the critical issue of support for change and the cultural anchoring of digital solutions (Akrich, 1992; Ajani and Govender, 2023; Oubibi and al., 2024).

One major finding remains the inequality of access to digital infrastructure (electricity, internet, computer equipment), especially in rural and disadvantaged areas (Alade and Mthetwa, 2025; Organization for Economic Co-operation and Development [OECD], 2023). This digital divide increases students' vulnerability and prevents the equitable implementation of educational innovations, including those based on AI. As a result, in many contexts, AI is perceived as an elitist technology unsuited to local realities (Chisom, Unachukwu, and Osawaru, 2023; Falebita and Kok, 2024; Huet, 2024; Modiba, Van den Berg and Mago, 2025).

Initial teacher training programs rarely include modules on educational AI, and curricular reforms remain in their infancy. Studies by Modiba, Van den Berg and Mago (2025) and Nyaaba and Zhai (2024) confirm the lack of structured training on generative AI in teacher education. This mismatch between pedagogical content and the needs of the 21st century is also highlighted by Laurillard (2012) and Van der Vlies (2020).

Most Ministries of Education in Africa still lack intelligent educational information systems capable of aggregating, analysing and predicting trends in performance or school dropout rates (Misra, 2022). This structural weakness limits the use of AI for governance, evaluation and personalization of learning pathways.

Policy landscape and regional strategies for AI in African education:-

The integration of AI into African education systems is unevenly shaped by diverse national priorities, institutional capacities and regulatory maturity. Across the continent, countries are experimenting with AI-enabled platforms for teaching, assessment and administration, yet few possess coherent, system-wide strategies that connect classroom practice to governance, ethics and workforce development (Chisom, Unachukwu, and Osawaru, 2023; Falebita and Kok, 2024). Continental agendas, including Smart Africa's digital transformation efforts and the African Union's Continental Education Strategy for Africa (CESA 16–25), offer scaffolding for policy convergence, but national

uptake remains heterogeneous (Huet, 2024; Alade and Mthetwa, 2025). Comparative insights from OECD work on digital strategies further underline the need for whole-of-system approaches that link infrastructure, skills, curriculum and regulation (OECD, 2023; van der Vlies, 2020).

In Ghana, policy attention to digitalization in teacher education has accelerated, with pilots focusing on generative AI literacy and blended professional development. However, most initiatives remain project-based and weakly tethered to national curriculum standards and classroom assessment norms, creating risks of fragmentation and shallow adoption (Chisom et al., 2023; Falebita and Kok, 2024).

In Rwanda, a comparatively clearer national vision links digital infrastructure with classroom technology use. Early use of AI-ready learning platforms positions Rwanda to test adaptive learning and analytics, but long-term governance data protection, algorithmic transparency and procurement standards require continued consolidation (Falebita and Kok, 2024; OECD, 2023). Building on digital literacy reforms, Kenya shows strong higher education and EdTech entrepreneurship energy. The main gap is a cross-sector policy that harmonizes school-level practices, teacher standards and ethical safeguards for AI-mediated assessment and student data (Chisom et al., 2023; van der Vlies, 2020).

In Cote d'Ivoire, momentum is growing in tertiary institutions and teacher training, but national frameworks specific to AI in schooling (ethics, curriculum integration, and capacity building) are emergent rather than consolidated, with opportunities to align with continental roadmaps and regional partnerships (Huet, 2024; Alade and Mthetwa, 2025). Smart Africa and AU–CESA 16–25. Both agendas encourage interoperable infrastructure and teacher upskilling and innovation ecosystems. Translating these into national policies calls for explicit AI-in-education compacts: ethical and data-governance baselines; competency standards for teachers; and curriculum guidance for age-appropriate AI literacies and sustainable financing models (Huet, 2024; Alade and Mthetwa, 2025). Cross-border collaboration, shared repositories of open educational data, benchmark assessments and procurement guidelines can reduce costs and strengthen sovereignty in regional cooperation while ensuring cultural and linguistic relevance (Alade and Mthetwa, 2025; OECD, 2023).

Evidence from OECD systems points to four levers that travel well to African contexts when adapted: strategy coherence (a single, living AI-in-education framework that ties goals to classroom practice); teacher capability (funded, staged professional learning anchored in classroom use); assessment and curriculum alignment (clear guidance on AI-supported formative/summative assessment); and governance and trust (transparent rules for data use, vendor accountability and bias) (OECD, 2023; van der Vlies, 2020).

Gaps include project-driven pilots without scale paths, limited teacher standards for AI use, nascent data protection enforcement in education, and weak mechanisms to evaluate learning impact (Chisom et al., 2023; Falebita and Kok, 2024; OECD, 2023). Opportunities include embedding AI within national teacher professional standards and preservice curricula; adopting continental ethical baselines; pooling procurement and evaluation across RECs (regional economic communities); and catalyzing local EdTech aligned with national languages and curricula (Huet, 2024; Alade and Mthetwa, 2025; van der Vlies, 2020).

The identified policy recommendations are as follows:

- Publish a national AI-in-education framework that operationalizes AU–CESA 16–25 and Smart Africa principles into curriculum, assessment and professional development roadmaps with measurable milestones (Huet, 2024; Alade and Mthetwa, 2025).
- AI-aligned teacher standards (with staged proficiency levels) should be mandated, and multiyear professional development focused on classroom tasks, not tools, should be financed (OECD, 2023; van der Vlies, 2020).
- Education-specific data governance (student privacy, the auditability of algorithms, vendor transparency) should be adopted to build trust and sovereignty (Falebita and Kok, 2024; OECD, 2023).
- Regional testbeds for shared evaluation protocols, cost-sharing procurement, and open datasets should be created to accelerate evidence-based scales (Alade and Mthetwa, 2025; Chisom et al., 2023).

Table 1:- Comparative Overview of AI Policy and Strategy Readiness in African Education by Region

AFRICAN SUB-REGION	AI POLICY READINESS	IMPLEMENTATION STATUS	TEACHER TRAINING INTEGRATION	GOVERNANCE MATURITY	KEY REFERENCES
West Africa (e.g., Ghana, Cote d'Ivoire, Senegal)	Emerging policy frameworks in draft or early adoption	Pilot programs in select urban areas	Limited; concentrated in higher education	Weak enforcement, low interministerial coordination	OECD (2023); Boateng &Kumbol (2024)
East Africa (e.g., Rwanda, Kenya, Uganda)	Advanced in pioneers (Rwanda), emerging elsewhere	Large-scale EdTech and AI pilots	Integrated into teacher PD in lead countries	Moderate; some regional collaboration via EAC	Falebita& Kok (2024); van der Vlies (2020)
Southern Africa (e.g., South Africa, Namibia)	Mature in South Africa; others in early adoption	Established AI-in-education programs	Strong in-service training frameworks	Moderate to high; ethical guidelines emerging	Cappelli & Akkari (2025); UNESCO (2025)
North Africa (e.g., Morocco, Egypt, Tunisia)	Well-developed national AI strategies	Scaling implementation through EdTech partnerships	Teacher digital training mandated in policy	High policy maturity; regional cooperation via AU & Arab League	Nyaaba& Zhai (2024); OECD

The AI policy landscape in Africa remains highly heterogeneous, with pioneers such as Rwanda and South Africa demonstrating mature integration strategies, while others are still in pilot stages (Falebita& Kok, 2024; Cappelli & Akkari, 2025). Regional economic communities such as ECOWAS and the EAC have facilitated collaborative frameworks, but disparities in teacher training and infrastructure persist (OECD, 2023; Boateng &Kumbol, 2024). The consolidation of ethical and regulatory guidelines is emerging, particularly in southern and North Africa (Nyaaba& Zhai, 2024; UNESCO, 2025).

Ethical and regulatory frameworks for AI in African classrooms:-

Without clear frameworks, AI adoption risks amplifying algorithmic bias, enabling intrusive surveillance, and eroding cultural autonomy (Floridi, 2014; Alade and Mthetwa, 2025). In contexts where sociotechnical infrastructures are uneven and legal protections are limited, these risks can undermine trust in educational technology and exacerbate inequities. AI systems deployed in classrooms (ranging from adaptive learning platforms to automated assessment tools) are often trained on datasets that reflect sociocultural contexts far removed from African realities. This can lead to biased recommendations or evaluations that disadvantage particular linguistic, cultural or gender groups (Alade and Mthetwa, 2025). Moreover, the widespread use of platforms that collect sensitive student data without transparent consent protocols raises concerns about surveillance and long-term data exploitation (Floridi, 2014). Cultural autonomy is further threatened when imported AI systems impose external pedagogical norms, marginalizing local knowledge systems and epistemologies.

Robust data protection laws tailored to education constitute a cornerstone of digital sovereignty. In countries such as Rwanda and Ghana, emerging legislative frameworks seek to regulate personal data use in digital learning environments, setting a precedent for regionally harmonized standards (Huet, 2024). However, on much of the continent, such legislation remains fragmented or unenforced, creating vulnerabilities in AI-enabled classrooms (Modiba, Van den Berg and Mago, 2025). Complementing legal safeguards, investment in local EdTech development is essential for ensuring that AI tools are culturally relevant, linguistically inclusive and responsive to national curricula. Building domestic capacity in AI design, deployment and evaluation not only reduces dependence on foreign vendors but also supports the creation of open educational resources aligned with African priorities.

A comparison of countries with more robust educational AI regulations versus those without reveals stark contrasts. In nations such as Rwanda, where data protection laws intersect with digital education policies, AI adoption isaccompanied by clearer procurement guidelines, accountability mechanisms for vendors and mandatory teacher training on ethical AI use (Huet, 2024). In contrast, in systems lacking such frameworks, AI deployment is largely unregulated, leaving decision-making to individual institutions or external providers often without consideration for bias mitigation, privacy safeguards or pedagogical appropriateness (Modiba, Van den Berg and Mago, 2025).

The policy recommendations are as follows:

- Education-specific AI ethics charters incorporating bias detection, transparency and accountability principles should be established.
- Robust data protection legislation with sector-specific provisions for education should be enforced.
- Regional cooperation should be promoted to develop common AI governance benchmarks aligned with the African Union's digital sovereignty agenda.
- Investment in local AI innovation ecosystems ensures that tools are developed and maintained within the continent, reflecting African cultural, linguistic and pedagogical contexts.
- By embedding AI integration within a coherent ethical and regulatory framework, African education systems can balance technological innovation with the imperatives of equity, sovereignty and cultural preservation.

Gender and inclusion in AI education:-

While AI has the potential to bridge educational gaps, its adoption can also reinforce existing inequities if access, design and implementation are not explicitly inclusive (Ajani and Govender, 2023; Oubibi et al., 2024). Empirical studies indicate that gendered disparities in access to AI-enabled learning tools persist across many African educational contexts. In several countries, boys are more likely to be granted extended computer lab time, participate in coding clubs or receive encouragement to explore emerging technologies, whereas girls often encounter implicit bias from teachers and peers (Ajani and Govender, 2023).

In addition, the limited integration of AI concepts into curricula for traditionally female-dominated disciplines reduces opportunities for girls to develop AI literacy early on (Oubibi et al., 2024). Such disparities risk perpetuating gender gaps in STEM participation and digital career pathways. Beyond gender, AI adoption in African classrooms must also account for compounded vulnerabilities. Rural girls face infrastructural constraints such as unreliable electricity, poor internet connectivity and a lack of digital devices, which are barriers that disproportionately affect their ability to benefit from AI-enhanced learning platforms (Alade and Mthetwa, 2025). Students with disabilities experience further exclusion when AI tools and platforms lack accessible design features such as screen readers, sign language interpretation or adaptive user interfaces (OECD, 2023). Without targeted interventions, these groups risk being excluded from both the immediate benefits of AI in education and the long-term opportunities in AI-related fields.

To align AI adoption with SDGs 4 and 5, several policy actions are recommended:

- Gender and accessibility audits are embedded into all AI procurement and deployment processes to ensure that platforms meet universal design standards (OECD, 2023; Alade and Mthetwa, 2025).
- AI literacy should be integrated into all subject areas, not only STEM, to normalize participation by girls and students from marginalized groups (Ajani and Govender, 2023).
- Rural inclusion programs such as mobile AI labs, community-based teacher training and subsidized device distribution should be targeted, with a focus on girls and students with disabilities (Oubibi et al., 2024; Alade and Mthetwa, 2025).
- Monitoring frameworks that track participation and performance disaggregated by gender, disability and location should be established to inform evidence-based interventions (OECD, 2023).

By incorporating inclusivity into the design, policy and practice of AI integration, African education systems can harness AI not only to modernize pedagogy but also to advance equity, ensuring that technological transformation serves all learners. This section synthesizes the key dimensions, challenges, and strategies for ensuring gender equity and broader inclusion in AI education within African contexts. It organizes the analysis into a structured table, linking each dimension to practical examples and recent bibliographic references.

Table 2:- Synthesis for ensuring gender equity and broader inclusion in AI education within African contexts

DIMENSION	DEFINITION	KEY CHALLENGES	PRACTICAL STRATEGIES	AFRICAN EXAMPLES	ILLUSTRATIVE REFERENCES
Gender Equity	Ensuring equitable participation of women and girls in AI-related learning and careers	Persistent gender gaps in STEM enrolment; lack of female role models; sociocultural barriers	Mentorship programs; gender-responsive pedagogy; scholarships for women in AI fields	Women in AI Africa mentorship initiatives; STEM girls' clubs in Ghana	OECD, 2023; Huet, 2024;Oubibi et al., 2024
Inclusion of Learners with Disabilities	Providing AI-enabled learning environments accessible to students with disabilities	Limited access to assistive technologies; absence of inclusive design in AI tools	Universal design for learning (UDL); AI-powered assistive apps; teacher training on inclusion	Use of AI sign-language recognition tools in South African classrooms	OECD, 2023;Cappelli&Akkari, 2025;Zickafoose et al., 2024
Rural and Marginalized Communities	Reducing digital and AI literacy gaps for learners in underserved areas	Poor connectivity; lack of devices; insufficient trained teachers	Subsidized connectivity; community digital hubs; mobile AI labs	AI-enabled offline learning platforms in rural Kenya	Falebita& Kok, 2024;Oubibi et al., 2024;Ajani&Govender, 2023
Cultural and Linguistic Inclusion	Ensuring AI tools support local languages and respect cultural contexts	Dominance of English/French in AI platforms; lack of local-language datasets	Development of low-resource language models; community codesign	Local-language AI chatbots for literacy in Nigeria	Huet, 2024;Oubibi et al., 2024;Chisom et al., 2023

RESEARCH METHODOLOGY:-

This study adopts an interpretive qualitative approach enriched with mixed methods to ensure both contextual depth and the robustness of findings. This strategy is well suited for analysing African education systems that are undergoing complex technological transitions with significant social implications (Ajani and Govender, 2023; Oubibi et al., 2024; Huet, 2024; Modiba, Van den Berg and Mago, 2025). It enables the cross-analysis of empirical field data (teachers, institutions, curricula) with normative theoretical frameworks (TPACK, educational sovereignty, digital commons theory).

The data collection tools used are as follows:

- TPACK Questionnaire(Technological Pedagogical Content Knowledge)A standardized self-assessment tool will be used to measure teachers' competencies across the TK (Technological Knowledge), PK (Pedagogical Knowledge) and CK (Content Knowledge) dimensions (Mishra and Koehler, 2006; Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024).
- The curriculum document analysis grid tool evaluates the explicit and implicit presence of AI in secondary education programs and initial teacher training curricula (Holmes et al., 2019; Boateng and Kumbol, 2024).
- Semi structured interview guide interviews with teachers, education inspectors, policymakers and training officials explore perceptions, barriers, and local innovations (Floridi, 2014; Zickafoose et al., 2024).
- The Territorial Case Studies African countries are Cote d'Ivoire, Ghana, and Senegal for comparative analysis. This method helps capture spatial dynamics and proposes contextualized models (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024; Huet, 2024; Modiba, Van den Berg and Mago, 2025).

Results and Analyses:-

Case studies of AI integration in African education:-

While the integration of AI into African education systems remains fragmented, several notable national initiatives provide valuable insights into both the potential and the limitations of current approaches. These case studies illustrate how local contexts, institutional readiness and governance structures shape the outcomes of AI adoption.
Ghana's Ministry of Education, in partnership with local teacher training colleges, launched a national pilot to introduce generative AI tools such as ChatGPT for lesson planning, content creation and formative assessment (Modiba, Van den Berg and Mago, 2025).

The program aimed to equip teachers with foundational AI literacy andintegrate AI into existing digital pedagogy frameworks. While initial feedback indicated increased teacher confidence in experimenting with AI tools, the project faced notable limitations. According to Nyaaba and Zhai (2024), the training lacked strong curricular alignment, resulting in inconsistent integration into classroom practice.

Furthermore, ethical considerations such as addressing algorithmic bias, ensuring academic integrity and protecting student data were insufficiently embedded, leading to concerns about sustainability and teacherpreparedness beyond the pilot phase. Rwanda has taken a more structured approach by deploying AI-powered learning management systems (LMSs) to select secondary schools as part of its broader digital education strategy (Zickafoose et al., 2024).

These LMS platforms integrate adaptive learning algorithms that personalize content delivery on the basis of student performance, providing real-time analytics for teachers to adjust instruction. Early results indicate improved engagement and differentiated learning outcomes, particularly in STEM subjects. However, the program also reveals scalability challenges (rural schools often lack stable connectivity, teachers require sustained professional development to leverage LMS features effectively, and data privacy protocols are still evolving to meet international best practices).

In 2023, Senegal implemented a pilot AI curriculum reform targeting upper secondary education with the goal of introducing AI concepts, ethics and applications across disciplines (Huet, 2024). The reform was accompanied by teacher training workshops and the introduction of AI-related modules in science and technology courses. While the initiative demonstrated strong political will and generated enthusiasm among urban schools, it encountered postimplementation challenges.

Many rural institutions lack the infrastructure and trained personnel to implement the curriculum effectively. Moreover, the absence of follow-up support and monitoring mechanisms led to uneven adoption, with some schools reverting to traditional teaching methods after the pilot period. Across these three cases, several common themes emerge: the necessity of aligning AI initiatives with national curricula, the importance of continuous teacher professional development and the critical role of infrastructure readiness.

Without robust governance frameworks, ethical guidelines and sustained resource allocation, pilot projects risk remaining isolated successes rather than catalysts for systemic transformation. These experiences underscore the need for integrated strategies that combine technological innovation with capacity building, policy coherence and inclusive access.

Table 3:- Comparative case studies (Ghana, Rwanda, Senegal)

Country	Initiative/Context	AI Focus	Reported Outcomes	Constraints/Risks	Policy & PD Implications	Core References
Ghana	National pilot using generative AI (e.g., for lesson planning, content creation, formative assessment)	Teacher productivity; lesson design; formative assessment	Increased teacher confidence; experimentation with AI tools	Weak curricular alignment; limited ethical guidance on bias, integrity, student data	Align with curriculum standards; embed AI ethics; sustained, staged PD for teachers	Modiba et al., 2025;Nyaaba&Zhai, 2024

Rwanda	AI-enabled LMS in select secondary schools within a broader digital strategy	Adaptive learning algorithms; real-time analytics	Improved engagement; more differentiated learning in STEM	Rural connectivity; sustained PD needs; evolving data-privacy protocols	Invest in infrastructure; continuous teacher coaching; strengthen data governance	Zickafoose et al., 2024
Senegal	Pilot AI curriculum reform (upper secondary) with teacher workshops and AI modules	AI concepts &ethicsacross disciplines	Strong political will; enthusiasm in urban schools	Rural infrastructure & staffing gaps; limited follow-up & monitoring	Postpilot support; targeted resourcing for rural areas; monitoring & evaluation	Huet, 2024

Ghana's pilot efforts increase teacher confidence in the use of generative AI, yet curricular alignment and ethical guidance remain uneven (Modiba, Van den Berg, & Mago, 2025; Nyaaba& Zhai, 2024). Rwanda's AI-enabled LMS deployments report improved engagement and differentiation, although persistent rural connectivity challenges and ongoing teacher coaching need a limited scale (Zickafoose et al., 2024). In Senegal, policy momentum is strong, and early reception is positive in urban settings; however, sustained support and rural resourcing are critical to avoid reform fatigue (Huet, 2024).

Comparative synthesis of readiness, governance and infrastructure:-

The integration of artificial intelligence in African education systems is shaped by significant variations in readiness, governance maturity and infrastructure availability. While some countries are experimenting with AI-enabled learning management systems (LMSs) and adaptive technologies, others are still laying the groundwork for basic digital access. A comparative synthesis across African subregions illustrates these disparities and highlights targeted opportunities for intervention (Zickafoose et al., 2024; Huet, 2024).

Table 4:-Comparative synthesis

African Subregion	AI Readiness Level	Governance Maturity	Infrastructure Availability	Key Challenges	Strategic Opportunities	APA Bibliographic References
West Africa (Ghana, Cote d'Ivoire, Senegal)	Moderate pilots in teacher training and curriculum innovation	Emerging some policy frameworks but limited enforcement	Variable with urban–rural divide remains significant	Limited rural connectivity; inconsistent teacher capacity	Leverage regional ECOWAS education agenda for AI curriculum and joint procurement	Zickafoose, A., Ilesanmi, O., Diaz Manrique, M., Adeyemi, A. E., Walumbe, B., Strong, R., Wingenbach, G., Rodriguez, M. T., and Dooley, K. (2024). Barriers and challenges affecting quality education (Sustainable Development Goal #4) in Sub Saharan Africa by 2030. Sustainability, 16(7), Article 2657. https://doi.org/10.3390/su16072657
East Africa (Rwanda, Kenya, Uganda)	High in leading countries AI-powered LMS and	Advanced in pioneers like Rwanda; nascent elsewhere	Moderate improving mobile penetration but uneven broadband	Sustainability of funding; data privacy laws under development	Regional cooperation on AI governance and teacher capacity	Huet, J.-M. (2024). L'intelligence artificielle et la digitalization de l'enseignement: des leviers essentiels pour l'avenir de la formation en Afrique.

	adaptive learning tools in use				through EAC framework	Communication, technologies et développement, (16).
Southern Africa (South Africa, Namibia)	High strong EdTech sector and research capabilities	More mature with regulatory structures and ethical guidelines emerging	Stronger infrastructure in urban areas but rural gaps persist	Digital divide across socioeconomic groups	Strengthen teacher professional development for rural schools; promote local EdTech solutions	Huet, J.-M. (2024). L'intelligence artificielle et la digitalization de l'enseignement: des leviers essentiels pour l'avenir de la formation en Afrique. Communication, technologies et développement, (16).
Central Africa (Cameroon, DRC)	Low minimal AI-specific projects in education	Weak with few dedicated AI governance frameworks	Low infrastructure deficits and political instability	Funding shortages; lack of teacher training	Target donor and AU-backed infrastructure investment; develop foundational AI literacy programs	Zickafoose, A., Ilesanmi, O., Diaz Manrique, M., Adeyemi, A. E., Walumbe, B., Strong, R., Wingenbach, G., Rodriguez, M. T., and Dooley, K. (2024). Barriers and challenges affecting quality education (Sustainable Development Goal #4) in Sub Saharan Africa by 2030. Sustainability, 16(7), Article 2657.

While SDG 4 (quality education) remains essential for the adoption of AI in education, aligning initiatives with other sustainable development goals can create broader development synergies:

- SDG 5 (gender equality) involves deploying AI tools to close gender gaps in access, participation, and skills development.
- SDG 9 (Industry, Innovation, and Infrastructure) adopts AI as a driver for the development of local education technology industries and digital infrastructure.
- SDG 12 (Responsible Consumption and Production) promotes environmentally friendly and ethically sourced AI solutions.
- SDG 17 (Partnerships for the Goals) strengthens intergovernmental and public–private partnerships to share resources, governance frameworks, and best practices in AI.

Critical analysis on temporal, spatial and uncertainty scales:-

The integration of AI into education cannot be conceived as an immediate reform. It falls within a long-term transformation trajectory of African education systems. This requires a progressive approach to capacity building, particularly through the adoption of the TPACK model, which structures technological, pedagogical, and content knowledge (Mishra and Koehler, 2006; Ajani and Govender, 2023; Oubibi and al., 2024).

National training plans spanning three to five years are therefore necessary to gradually train teachers, starting with awareness of AI fundamentals and then moving toward contextualized use within specific disciplines. For example, Zickafoose et al. (2024) recommended a three-phase strategy: training of trainers, curriculum adaptation, and evaluation and sustainability. This temporal phasing is essential to avoid deepening the technological divide.

Africa is not a homogeneous bloc. The linguistic, socioeconomic, and institutional diversity between and within countries necessitates a spatialized analysis of AI integration strategies. While some cities, such as Kigali or Accra, are piloting AI tools in secondary schools, many rural areas remain deeply affected by the digital divide (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024). Comparative studies (Huet, 2024; Modiba, Van den Berg and Mago, 2025) highlight significant gaps between the Francophone and Anglophone education systems as well as

between centralized public policies (Senegal) and localized experiments (Cote d'Ivoire). This supports the need for differentiated territorial diagnostics and adaptable pedagogical frameworks at the local level (Boateng and Kumbol, 2024).

AI integration in education is subject to substantial uncertainties that must be anticipated to develop resilient policies. These uncertainties include the following:

- The rapid evolution of generative technologies (conversational AI, adaptive systems).
- Ethical risks are linked to data protection, algorithmic surveillance and bias reproduction (Floridi, 2014; Alade and Mthetwa, 2025).
- The volatility of education policies in politically or financially unstable contexts.

A prospective approach is therefore essential. It enables the development of differentiated scenarios such as an optimistic scenario based on open pan-African cooperation or a pessimistic scenario involving technological importation without educational sovereignty (Holmes et al., 2019; Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024). These scenarios inform the design of adaptive mechanisms such as continuous training, strategic monitoring and guided local experimentation.

Discussion and perspectives:-

Teacher professional development models for AI competency:-

Professional development models for AI competency must therefore be anchored in established pedagogical frameworks adapted to local contexts and designed for scalability. The technological pedagogical content knowledge model provides a robust foundation for structuring these competencies but requires expansion to address AI-specific skills, here conceptualized as TPACK-AI (Mishra and Koehler, 2006; Boateng and Kumbol, 2024). In preservice teacher education, TPACK-AI modules should introduce foundational AI concepts, their pedagogical applications and the ethical considerations surrounding their use.

For in-service training, modules should focus on subject-specific application integration into existing curricula and troubleshooting AI-driven tools in real classroom settings. The TPACK-AI framework ensures that TK is developed alongside PK and CK, fostering a holistic approach to AI integration (Mishra and Koehler, 2006). Boateng and Kumbol (2024) emphasized that contextualization through local case studies, culturally relevant datasets and language-appropriate tools is essential for teacher engagement and the transfer of learning.

Blended learning models offer a flexible and scalable route to building AI competency among teachers. These approaches combine face-to-face workshops with online modules, enabling iterative learning and reflection (Ajani and Govender, 2023). In practice, synchronous sessions can be used for collaborative problem-solving and peer exchange, whereas asynchronous modules provide self-paced learning on AI fundamentals, ethics and subject-specific applications (Oubibi et al., 2024). Such models are particularly valuable in African contexts where geographic and infrastructural disparities require adaptive training delivery.

Effective teacher professional development must include robust evaluation mechanisms to track skill acquisition and ensure sustained competency growth. Cappelli and Akkari (2025) recommend the use of a combination of self-assessment surveys, classroom observation rubrics and digital portfolios where teachers document AI-integrated lesson plans and reflections. Continuous feedback loops through coaching, peer review and microcredentialing reinforce skill retention and encourage iterative improvement. These mechanisms also enable training providers toadapt content and delivery methods in response to emerging challenges and technological shifts.

The strategic recommendations are as follows:

- Institutionalize TPACK-AI modules in teacher education curricula and professional development frameworks.
- Leverage blended learning models to overcome logistical and resource constraints in diverse African contexts.
- Multidimensional evaluation tools that measure not only technical proficiency but also ethical application and pedagogical integration of AI should be implemented.
- Create communities of practice for continuous peer learning and knowledge exchange with AI in education.

By embedding AI literacy into the professional identity of teachers, African education systems can ensure that AI serves as a tool for inclusive, ethical and contextually relevant pedagogical transformation.This section presents

structured models for enhancing teacher professional development (PD) in AI competencies, with a focus on African educational contexts. The table details each model's scope, implementation methods, benefits, challenges, African examples, and supporting bibliographic references.

Table 5:-Structured models for enhancing teacher professional development (PD) in AI competencies in African educational contexts

PD Model	Scope & Focus	Implementation Methods	Benefits	Challenges	African Examples	Illustrative References
TPACK-based AI PD	Integrating Technological, Pedagogical, and Content Knowledge with AI-specific competencies	Workshops combining AI tools training, pedagogical integration, and content adaptation	Holistic teacher capacity; better alignment of AI use with subject pedagogy	Need for ongoing mentoring; context-specific adaptation	Rwanda's AI-enhanced STEM teacher training	Mishra & Koehler, 2006;Cappelli&Akkari, 2025;Modiba et al., 2025
Mentorship & Peer Learning	Pairing novice AI educators with experienced AI-integrating teachers	Peer coaching, collaborative lesson planning, observation-feedback cycles	Sustained skills development; builds teacher community	Limited availability of experienced AI mentors	Women in AI Africa mentorship for educators	Ajani & Govender, 2023; Huet, 2024; OECD, 2023
Microcredentialing& Badging	Short, targeted certifications on AI tools and ethics	Online or blended modules; project-based assessment	Flexible, scalable skill recognition	Risk of superficial engagement without practice integration	UNESCO microcredentials for AI literacy	Oubibi et al., 2024;Falebita& Kok, 2024;Chisom et al., 2023
School-based Professional Learning Communities (PLCs)	Continuous, collaborative AI integration practice within schools	Weekly AI-focused PLC meetings; shared resource banks	Embedded PD in daily practice; fosters innovation culture	Requires strong school leadership and culture	South African school AI PLC pilots	OECD, 2023;Zickafoose et al., 2024;Nyaaba&Zhai, 2024

Training scenario for inclusive AI integration in African education systems:-

The proposed scenario aims to equip African teachers and policymakers with tools for critical, pedagogical, and ethical appropriation of AI. It aligns with the TPACK model (Mishra and Koehler, 2006), the principles of educational digital sovereignty (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024) and sustainable development goals (SDGs) 4, 5, 9, and 17.

The scenario is guided by the following principles:

- Competency-based approach (CBA) adapted to teacher profiles (urban, rural, experienced, novice).
- Active and collaborative pedagogy combining in-person and remote learning modalities.
- Formative and reflective assessment, including self- and peer-assessment.
- Operational transfer to pedagogical practices anchored in national curricula.

The expected outcomes of this training scenario include the following:

- Development of contextualized TPACK-AI competency frameworks.
- The creation of pilot modules integrating AI into scientific and literary disciplines.
- The adoption of a shared ethical charter for educational AI use.
- The formulation of national dissemination plans tailored to each target country.

Towards critical and restorative literacy in African education systems in the age of AI:-

Digital literacy is no longer limited to technical tool use; it must now encompass a critical understanding of emerging AI-based solutions, including generative AI, adaptive learning platforms and intelligent tutoring systems. In African contexts, the lack of structured teacher training in educational AI is a major barrier to empowerment (Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024; Huet, 2024). Pilot initiatives such as Ghana's generative AI training project reveal superficial appropriation, often centered on using ChatGPT without curricular or ethical integration (Modiba, Van den Berg and Mago, 2025; Nyaaba and Zhai, 2024).

The rise of educational AI comes with risks such as algorithmic bias, facilitated plagiarism, dehumanization of pedagogical relationships and nonconsensual surveillance of learners (Floridi, 2014; Alade and Mthetwa, 2025). For example, some platforms used in African schools collect sensitive data without transparent consent mechanisms or local regulation, increasing digital vulnerabilities (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024).Preventing such distortions thus becomes an ethical, institutional and legal priority. It calls for specific teacher training in detecting misuse, understanding algorithmic regulation and safeguarding data privacy (Holmes et al., 2019).

The responsible integration of AI into African education must align with the Sustainable Development Goals (SDGs), particularly:

- SDG 4 (quality education) involves contextualizing AI tools in curricula.
- SDG 5 (Gender Equality) ensures access to technology for girls and women.
- SDG 12 (Responsible Consumption) promotes sustainable and informed technology choices.

Recent studies (Zickafoose et al., 2024; Ajani et al., 2023; Oubibi et al., 2024) emphasize that unregulated AI adoption exacerbates inequalities between rural and urban areas, between genders and between the Francophone and Anglophone education systems. In this context, the development of national ethical frameworks has emerged as a responsible best practice. The digital transformation of African education systems must not only be forward-looking.

It must also be restorative; that is, it is capable of repairing existing inequalities, addressing the negative effects of unregulated experimentation, and rebuilding teachers' trust in digital tools. The protection and restoration approach is aligned with SDG 13 (climate action) and SDG 15 (life on land), as it emphasizes strategies for resilience and educational justice. For example, the lack of institutional support following the failure of a pilot AI project in Senegal in 2023 left teachers disoriented and resulted in lasting mistrust (Huet, 2024; Modiba, Van den Berg and Mago, 2025). This underscores the need for mechanisms of pedagogical recovery.

Discussion:-

The findings of this study confirm that the integration of artificial intelligence into African educational systems cannot be reduced to mere technological transfer or instrumental modernization. It requires a reinvention of pedagogical frameworks, contextualized ethical reflection and a reconfiguration of educational policies.

The analysis of practices reveals that while some countries, such as Ghana, Rwanda, and Kenya, are launching structured initiatives around AI in education (Chisom, Unachukwu and Osawaru, 2023; Falebita and Kok, 2024), the majority of states still face a lack of clear strategies, basic infrastructure and adequate teacher training (Zickafoose and al., 2024). These disparities widen the digital divide (Alade and Mthetwa, 2025), both between countries and within rural, urban, northern and southern territories.

Most AI educational platforms used in Africa are imported (Holmes et al., 2019). This raises issues of digital sovereignty, as learners' data, algorithm design and cultural references are rarely locally controlled. This technological dependence weakens the capacity for curricular adaptation, particularly in African languages or nonformal learning contexts (Huet, 2024; Modiba, Van den Berg and Mago, 2025). The use of the TPACK model

helps structure teacher capacity-building at the intersection of content knowledge, pedagogical knowledge and technological knowledge (Mishra and Koehler, 2006). However, applying this model in African contexts requires adaptation that takes into account the diversity of resources, the linguistic realities, and the social representations of AI (Ajani and Govender, 2023; Oubibi et al., 2024).

The risks associated with the unregulated use of AI (bias, surveillance, and exclusion) make it urgent to develop ethical charters and local regulatory frameworks (Floridi, 2014; Alade and Mthetwa, 2025). Aligning with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education), SDG 5 (Gender Equality) and SDG 9 (Innovation), provides an operational framework to guide public policies. The recommendations from this research are rooted in a logic of cognitive justice (Huet, 2024; Modiba, Van den Berg and Mago, 2025) and the protection of educational communities.

In addition to providing technical opportunities, AI can be mobilized to address structuralinequalities in African education, provided that its use is embedded in inclusive, participatory and sovereign strategies. This requires a paradigm shift: AI should not be seen as an end in itself but as a tool in the service of a renewed African educational project centered on learners, cultural diversity and territorial resilience.Embedding AI within a multi-SDG framework strengthens its potential not only as an educational innovation but also as a catalyst for equitable, sustainable, and collaborative development in Africa.

This variation demonstrates that AI integration is not only a technological issue but also a governance and equity challenge. In particular, governance maturity—defined by the existence of ethical guidelines, data protection laws, and transparent procurement processes—strongly correlates with sustainable AI adoption(Huet, 2024).Strengthening links to the Sustainable Development Goals.

While SDG 4 (quality education) remains the central driver of AI adoption in education, linking AI initiatives to other sustainable development goals can create broader development synergies:

- SDG 5 (Gender Equality) ensures that AI tools are designed and deployed to close gender gaps in access and participation.
- SDG 9 (Industry, Innovation, and Infrastructure) uses AI adoption in schools as a catalyst for local EdTech innovation and digital infrastructure expansion.
- SDG 12 (Responsible Consumption and Production) promotes energy-efficient AI solutions and ethical procurement to minimize environmental impact.
- SDG 17 (Partnerships for the Goals) strengthens cross-border collaborations for shared AI policy frameworks, opens educational resources, and pools procurement mechanisms.

By situating AI in education within a multi-SDG framework, policymakers can ensure that investments in technology contribute to systemic transformation, inclusive participation, and sustainable growth across the continent. This section synthesizes the key cross-cutting insights emerging from the previous sections, highlighting thematic intersections, implications for African education systems, and opportunities for policy, pedagogy, and research. The table provides an integrated overview to facilitate understanding and further strategic action.

Table 6:- Integrated overview to facilitate understanding and further strategic action

Theme	Key Insights	Cross-links to Other Sections	Implications	Illustrative References
Policy-Practice Alignment	Policies for AI in education must be translated into actionable school-level strategies	Links with Sections 9 (Policy Landscape), 7 (Training Scenario), 11 (Teacher PD)	Need for implementation roadmaps, capacity building, and localized policy adaptation	OECD, 2023;Falebita& Kok, 2024;Cappelli&Akkari, 2025
Ethical and Inclusive AI	Ethics must be embedded into teacher training, curriculum, and technology design	Links with Sections 10 (Gender & Inclusion), 9 (Ethical Frameworks), 8	Development of culturally relevant AI ethics guidelines for schools	Huet, 2024;Oubibi et al., 2024;Chisom et al., 2023

		(Critical Literacy)		
Teacher Capacity for AI	Professional development requires continuous, collaborative, and context-specific approaches	Links with Sections 11 (Teacher PD), 7 (Training Scenario)	Institutionalize AI PD in teacher training colleges and ministries of education	Mishra & Koehler, 2006;Modiba et al., 2025;Ajani&Govender, 2023
Infrastructure and Access	Bridging rural–urban digital divides is central to equitable AI integration	Links with Sections 9 (Regional Strategies), 10 (Inclusion)	Invest in connectivity, low-cost devices, and offline AI-enabled platforms	Zickafoose et al., 2024; OECD, 2023;Falebita& Kok, 2024
Critical and Restorative Literacy	Empowering learners to critically assess AI outputs while restoring cultural and linguistic contexts	Links with Sections 8 (Critical Literacy), 9 (Ethics)	Integrate critical AI literacy into curricula at multiple education levels	Laurillard, 2012; Luckin, 2017; Huet, 2024

The following model visually summarizes the proposed strategy for AI integration in African education systems. It connects the identified challenges with the TPACK-AI model, a professional development roadmap, policy levers, expected outcomes, and broader impacts aligned with the SDGs.

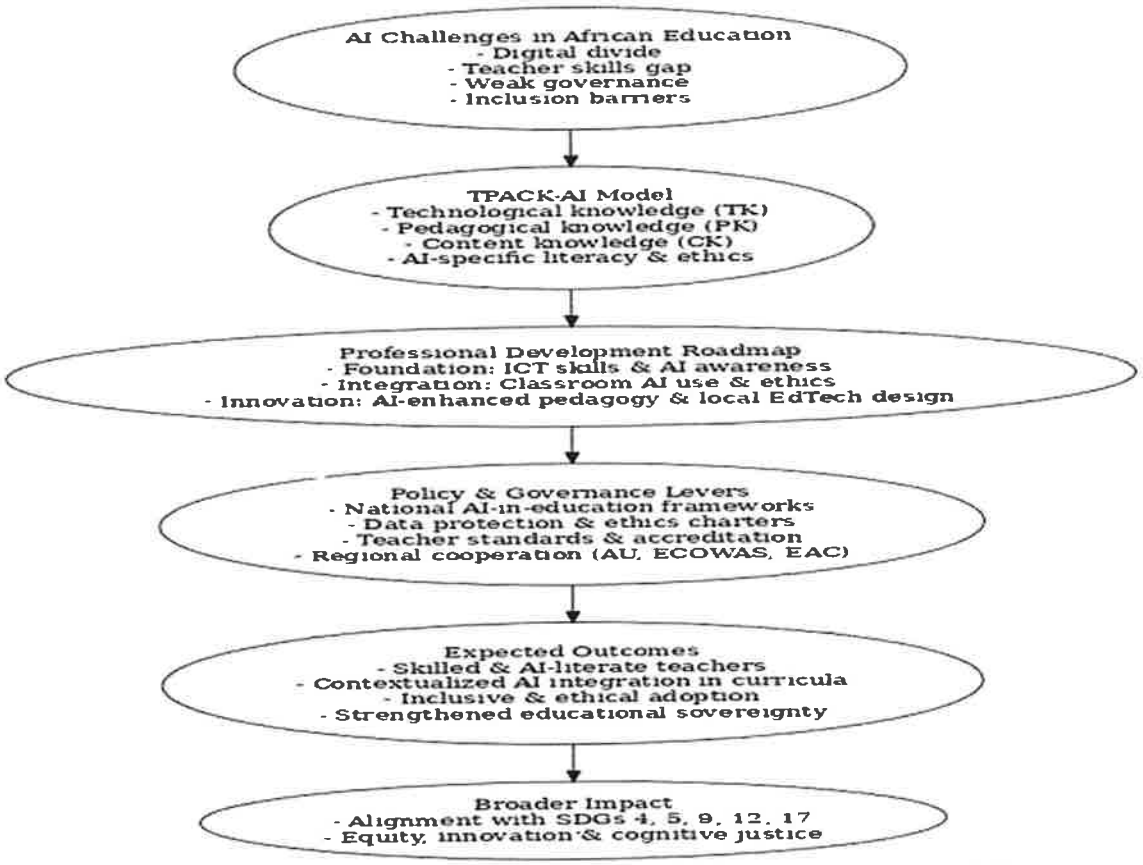

Figure 1:-TPACK-AI Professional Development and Policy Integration Framework.

This model shows how systemic challenges (digital divide, skills gaps, governance) connect to the TPACK-AI model and a phased teacher professional development roadmap, supported by policy and governance levers, leading to skilled teachers, inclusive AI adoption, and alignment with SDGs 4, 5, 9, 12, and 17.

Note: This flowchart illustrates the logical sequence of AI integration in African education. It begins with systemic challenges (digital divide, teacher gaps, governance), aligns them with the TPACK-AI model, and proposes a professional development roadmap in three phases (foundation, integration, innovation). It also highlights the importance of policy and governance levers (national frameworks, data protection, regional cooperation) in shaping inclusive outcomes. The model shows how these processes lead to skilled teachers, contextualized curricula, and inclusive adoption of AI, ultimately strengthening educational sovereignty and advancing SDGs 4, 5, 9, 12, and 17.

Conclusion:-

As highlighted in Figure 1, the proposed TPACK-AI framework links teacher development, governance levers and SDG outcomes.The integration of artificial intelligence into African educational systems has emerged as both a strategic necessity and a systemic challenge. The rapid rise of AI in the educational field is reshaping the landscape of teaching and learning on a global scale. In Africa, this transformation offers unprecedented opportunities to address systemic challenges related to educational quality, equity and governance. However, it also raises significant risks in terms of digital divides, ethical appropriation and pedagogical sovereignty. This research highlights the need for a training strategy based on the TPACK model adapted to African contexts to enable teachers to develop critical literacy in AI tools, prevent pedagogical distortions and promote responsible practices aligned with the Sustainable Development Goals (SDGs). The data collected and the practices observed underscore the importance of a contextualized competency framework, an ethical governance structure and restorative mechanisms capable of rebuilding trust within educational communities.

Far from being a mere question of technological innovation, the integration of AI into education is a political, cultural and ethical issue. It calls for strong regional coordination, targeted investments in initial and continuing teacher education, and shared regulation of digital uses in education.

Ultimately, envisioning AI in African educational systems is about shaping the future of training, cognitive justice and the continent's intellectual sovereignty. This strategic undertaking involves governments, universities, teachers, technology partners and citizens in a collective and responsible dynamic.The expected outcomes include the identification of TPACK competency gaps, the proposal of a national AI training strategy, the development of competency frameworks adapted to African contexts and the reduction of the educational digital divide.

The integration of artificial intelligence (AI) into African education systems presents both a transformative opportunity and a strategic challenge. While pilot initiatives and emerging policies demonstrate that AI can enhance teaching, personalize learning and support data-driven decision-making, sustainable impact requires coordinated action across governance, capacity building and infrastructure development. Policymakers must move beyond fragmented projects to establish coherent national and regional frameworks that align AI adoption with curriculum reform, teacher professional development and ethical governance (Alade and Mthetwa, 2025).

Teacher training institutions play a central role in embedding AI literacy and pedagogical integration skills into both preservice and in-service programs. This includes leveraging contextually adapted frameworks such as TPACK-AI to ensure that technological knowledge is developed alongside pedagogical and content expertise (Boateng and Kumbol, 2024). Likewise, EdTech entrepreneurs must commit to designing solutions that are culturally relevant, linguistically inclusive, and compliant with robust data protection standards, thus contributing to digital sovereignty. To facilitate sustained progress and cross-country learning, the establishment of Pan-African AI at Education Observatories is imperative. This body would monitor policy implementation, track teacher competency development, evaluate the impact of AI initiatives on learning outcomes, and disseminate best practices across the continent (Alade and Mthetwa, 2025; Boateng and Kumbol, 2024). This observatory could serve as a hub for multistakeholder collaboration, ensuring that AI in African education is guided by shared values of equity, innovation, and sustainability.

Ultimately, realizing the potential of AI in African education demands a collective commitment: policymakers to create enabling environments, teacher training institutions to prepare educators for an AI-driven future, and EdTech innovators to deliver inclusive and contextually grounded solutions. Coordinated efforts at both the national and continental levels will be essential to ensure that AI becomes a lever for educational equity, innovation, and long-term development.

Exploring reinforcement learning and adversarial training mechanisms could further strengthen the system's resilience to novel and adversarial threats. Lastly, although the dataset used in this study reflects real-world conditions, future evaluations on larger and more heterogeneous datasets will be necessary to assess generalizability across different threat landscapes.

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