African Journal of Inter/Multidisciplinary Studies (AJIMS)
Volume 7, Issue 2, pp. 1-13
e-ISSN: 2663-4589

Rethinking Education for a More Inclusive and Future-Ready AI Era

Kayode Oyetade and Tranos Zuva

[1]**Department of Computer Sciences, Vaal University of Technology, Vaal, South Africa**

Abstract: This study examines the evolving role of education in preparing learners for an AI-driven future within the context of the fourth industrial revolution (4IR) and the potential of generative artificial intelligence (gAI). As AI increasingly reshapes labor markets, education systems must move beyond traditional, industrial-age models to cultivate adaptive, ethical, and future-ready competencies. Guided by connectivism, social constructivism, and transformative learning, the study employs a descriptive literature review to identify essential competencies, including AI literacy, digital fluency, critical thinking, ethical reasoning, and lifelong adaptability. It evaluates how current educational practices, policies, and curricula address these demands. The analysis draws on global examples and contextual insights from the Global South, with a particular focus on South Africa, highlighting curriculum reforms, upskilling and reskilling strategies, and inclusive policy interventions. Findings reveal both the opportunities and systemic challenges of AI integration, including digital inequities, underprepared educators, and misaligned curricula. The study concludes by proposing a strategic, phased framework for educational transformation that integrates ethical governance, teacher capacity-building, interdisciplinary learning, and cross-sector collaboration, thereby positioning education as a driver of inclusive, responsible, and socially responsive engagement in the era of gAI.

Keywords: AI literacy; artificial intelligence (AI); curriculum innovation; education reform; inclusive education

CORRESPONDENCE
Email: kayoyetade@gmail.com

EDITORIAL DATES
Received: 14 April 2025
Revised: 15 December 2025
Accepted: 15 December 2025
Published: 31 December 2025

DOI: https://doi.org/10.51415/ajims.v7i2.2707

Introduction

The fourth industrial revolution (4IR) continues to redefine how societies live, learn, and work through the convergence of emerging technologies such as artificial intelligence (AI), robotics, big data, automation, and the Internet of Things (IoT) (Ibegbulam et al., 2023; Oyetade et al., 2025). These innovations are dissolving the boundaries between physical, digital, and biological systems, transforming industries and labor markets while exposing the limitations of traditional education systems that prioritize rote learning and standardization over critical and adaptive thinking (Chowdhury et al., 2024; Xing et al., 2018). Among these technologies, generative AI (gAI), capable of producing original text, images, and code, has emerged as a disruptive force that revolutionizes content creation, decision-making, and problem-solving (Oyetade & Zuva, 2025; Rane, 2023). While it enhances creativity and interdisciplinary

learning, it also raises concerns related to ethical implications, job displacement, and the obsolescence of conventional skills (Amankwah-Amoah et al., 2024; Rane, 2023). In response, two concepts central to this transformation are AI literacy and digital fluency. AI literacy refers to an individual's ability to understand, evaluate, and interact effectively with AI systems, encompassing technical knowledge, critical awareness of ethical and social implications, and responsible usage (Long and Magerko, 2020; Ng et al., 2021). Digital fluency, on the other hand, extends beyond basic technological proficiency to include the confident, critical, and creative use of digital tools for communication, collaboration, and problem-solving (Cain & Coldwell-Neilson, 2024; Johan et al., 2023).

Developing these competencies requires pedagogical approaches that integrate technical, cognitive, and ethical dimensions of learning thereby preparing learners for an AI-driven and knowledge-based society (Kayyali, 2024; Luckin, 2025). However, many existing systems remain anchored in industrial-age paradigms emphasizing standardization, content delivery, and siloed disciplines leaving learners underprepared for the demands of an AI-driven future (Chowdhury et al., 2024; George & George, 2024). This study explores the reimagining of education to equip future-ready learners for the gAI era, highlighting the cultivation of fundamental competencies, pedagogical innovation, and legislative frameworks that facilitate inclusive and ethical AI integration. To address this aim, the study employs a descriptive literature review methodology synthesizing findings from peer-reviewed articles, policy reports, and frameworks published between 2015 and 2025. The review study utilizes connectivism, social constructivism, and transformative learning to examine how education may encourage flexibility, ethical involvement, and lifelong learning in an AI-enhanced environment. The key objectives of this research are:

- To identify essential future skills such as problem-solving, adaptability, and data literacy.
- To assess the effectiveness of current educational models in fostering these competencies.
- To examine innovative curricular strategies that support upskilling and reskilling efforts; and
- To propose policy interventions that align education with evolving labour market needs.

The study's novelty lies in drawing insights from the Global South, particularly South Africa, to articulate a strategic framework for educational transformation that is technologically responsive, socially inclusive, and ethically grounded, providing practical guidance for policymakers, educators, and institutional leaders in navigating the AI transition toward inclusive, future-ready societies.

Theoretical framework

The integration of AI into education within the 4IR context necessitates theoretical foundations that explain how learners acquire knowledge, interact with intelligent systems, and develop ethical awareness. Three complementing theories: connectivism, social constructivism, and transformative learning are used in this study. Each provides a unique perspective on how AI literacy and digital fluency might be achieved in modern education.

Connectivism posits that learning occurs through the formation and navigation of networks comprising individuals, digital tools, and information nodes (Alam, 2023; Mukhlis et al., 2024). In AI-enhanced environments, learners construct knowledge dynamically by connecting with adaptive systems, online communities, and data-driven resources (Burton, 2024). This theoretical lens underpins AI literacy, as learners must understand, evaluate, and synthesize AI-generated knowledge within distributed networks.

Social Constructivism emphasizes that learning is a socially mediated process shaped by interaction and the shared meaning-making that results from it (Mishra, 2023). AI-supported tools such as chatbots, collaborative platforms, and simulations facilitate dialogic and inquiry-based learning enabling learners to co-construct knowledge while developing digital fluency through collaboration and ethical dialogue (Lai, 2025).

Transformative learning theory emphasizes the importance of promoting critical reflection, self-awareness, and ethical decision-making through engagement with complex and often disorienting experiences (Alam, 2022). In AI-driven contexts, learners encounter dilemmas such as algorithmic bias and data privacy, promoting reflective transformation and ethical literacy (Burton, 2024).

In conclusion, the integration of connectivism, social constructivism, and transformative learning provides a robust foundation for reimagining education as a technologically responsive, ethically grounded, and socially

inclusive system that cultivates learners who are adept, responsible, and conscious participants in an equitable, AI-driven future. The next section discusses the methodology adopted by this study.

Methodology

This study employs a descriptive literature review to examine how education systems can respond to the challenges and opportunities presented by gAI within the context of the 4IR. Guided by connectivism, social constructivism, and transformative learning, it synthesizes global and interdisciplinary insights to identify strategies for developing learners who are technologically competent, ethically responsible, and socially conscious. The descriptive approach enables focused analysis of educational strategies, curriculum innovations, and policy interventions while balancing breadth with thematic depth. To ensure rigor and transparency, the study employed systematic search strategies, clearly defined inclusion and exclusion criteria, and rigorous quality screening. This methodology offers a credible synthesis that supports actionable recommendations for designing inclusive, adaptive, and future-ready learning environments in the era of AI.

Google Scholar, Scopus, and IEEE Xplore were utilized for searches because of their extensive interdisciplinary content, focus on peer-reviewed and evidence-based research, and availability through university subscriptions. The terms used included "Generative AI," "AI in education," "AI literacy," "future skills," and "interdisciplinary education." Boolean operators refine searches for relevance and inclusivity. Certain inclusion and exclusion criteria were used to preserve the review's quality, rigor, and relevance:

Inclusion Criteria	**Exclusion Criteria**
Articles published between 2015 and 2025 were chosen to reflect current thinking and developments	Articles published before 2015 were dropped to maintain temporal relevance to recent AI advancements.
Articles addressing the intersection of AI and education, particularly focusing on skills development, curriculum innovation, or workforce alignment.	Non-peer-reviewed journals and conference proceedings lacking theoretical or methodological rigor.
Articles from peer-reviewed journals and conference proceedings.	Articles not explicitly related to education, AI integration, or skills transformation were dropped.
Articles written in English language publications.	

The study employed thematic analysis to identify patterns, insights, and emerging frameworks in the selected literature, enabling an in-depth synthesis of findings across disciplines and capturing both theoretical and empirical dimensions of educational transformation, which are as follows

- Repeatedly reading each source allowed for a thorough comprehension of the literature.
- Using both deductive and inductive methods, key element were methodically coded.
- AI literacy, ethical education, reskilling techniques, and inclusive learning ecosystems were among the broad themes that emerged from the clustering of coded data.
- To guide strategic educational reforms, themes were analyzed using the frameworks of connectivism, social constructivism, and transformative learning.

The review covered 56 studies published between 2015 and 2025 that matched the inclusion criteria.

The data in Table 1 shows a steady and significant growth in the number of studies over the three periods. Between 2015 and 2019, research activity was relatively low, with only five studies published. This increased sharply to 14 studies from 2020 to 2022, likely reflecting rising interest, technological advancements, or global events that heightened attention in the field. The most dramatic surge occurred between 2023 and 2025, with 37 studies, indicating a rapidly expanding research landscape and a substantial shift in academic or industry focus for gamification during this period.

Table 1. Distribution of Included Studies by Year

Period	**Number of Studies**
2015–2019	5
2020–2022	14
2023–2025	37

Literature review

The research on the 4IR and gAI highlights how the nature of work and the skills needed for a technology-driven economy have drastically changed. Beyond technical skills, education must cultivate adaptability, critical thinking, ethical reasoning, and digital fluency to prepare learners for the future workforce. This section is structured around three themes: (1) critical future skills; (2) the shortcomings of existing educational models; (3) strategies for upskilling and reskilling. Examples from international reforms and pilot projects show how these skills are being integrated into learning systems.

Essential future skills for the gAI era

The global workforce is undergoing a profound shift as gAI technologies automate both manual and cognitive tasks, transform existing roles, and create entirely new professions. Unlike previous industrial revolutions, this transition affects a broader range of occupations, requiring hybrid competencies that extend beyond technical expertise (George & George, 2024; Olaniyi et al., 2024). Emerging roles, including AI ethicists, human-machine interaction designers, and data governance specialists, highlight the need for interdisciplinary skill sets. While AI-driven augmentation enhances productivity and innovation, it also risks job displacement in routine tasks, contributing to labor market polarization (Callari et al., 2024; George & George, 2024). This landscape necessitates educational strategies that prioritize dynamic skill development, cultivate workforce resilience, and promote equitable access to emerging opportunities (Challoumis, 2024). Four core skill domains are foundational for success in an AI-integrated workforce.

- **Adaptability and lifelong learning** are critical in an era of accelerated technological change. Unlike past industrial periods where skills remained relevant for decades, professionals today must continuously evolve in response to new tools, platforms, and work environments (Challoumis, 2024). Therefore, a key component of workforce readiness is lifelong learning, which is the continuous acquisition and improvement of information and skills. Educational institutions can support this through adaptable learning pathways, including micro-credentials, hybrid models, and experiential learning, which foster sustained skill development across diverse career trajectories (Challoumis, 2024; Niyomves et al., 2024).
- **Critical thinking and ethical decision-making** are increasingly essential as AI systems influence complex decision processes. In uncertain situations, professionals must assess AI-generated results, recognize biases, and make well-informed decisions (Rezaei et al., 2025). In addition to technical proficiency, this calls for the capacity to analyze facts, pose insightful queries, and consider wider societal implications. Educational models that emphasize inquiry-based learning, ethical reflection, and real-world problem-solving are key to developing these capacities (Chu et al., 2021).
- **Ai literacy and digital competence** encompass more than basic digital skills. Learners must understand algorithmic processes, interpret outputs critically, and engage responsibly with intelligent systems across disciplines (Asrifan et al., 2025; Long and Magerko, 2020). Embedding AI literacy through primary, secondary, and tertiary education via interdisciplinary courses, simulations, and community-based initiatives promotes both digital inclusion and societal readiness (George & George, 2024; Pedro et al., 2019). Ethical awareness is an integral component, ensuring that AI tools are applied responsibly.
- **Interdisciplinary and human-centered competencies** complement technical expertise, emphasizing skills that AI cannot replicate, including empathy, creativity, communication, and ethical reflection. Integrating STEM knowledge with insights from the humanities, social sciences, and ethics enables professionals to develop socially responsible, context-aware solutions. Pedagogical strategies promoting collaboration, systems thinking, and reflective analysis cultivate these capacities (Ajiga et al., 2025; Alrassi et al., 2021). Framed through Connectivism, these skills represent nodes in a broader learning network, where learners navigate and integrate knowledge via AI-enhanced tools. Transformative Learning further underscores reflective, value-driven engagement in developing adaptive and ethically grounded thinkers.

Together, these skill domains form a foundation for preparing learners to navigate the complexities of the AI era. Educational strategies that integrate adaptability, critical thinking, AI literacy, and interdisciplinary human-centered competencies can foster resilient, socially responsible, and future-ready professionals capable of thriving in an AI-driven workforce.

Evaluating current educational models and curriculum reforms

The accelerating pace of technological innovation, particularly in artificial intelligence (AI), has revealed deep structural weaknesses in traditional educational systems that remain grounded in industrial-age paradigms. These models often emphasize standardized assessments, rigid disciplinary boundaries, and uniform pedagogies that fail to prepare learners for the adaptive, interdisciplinary demands of an AI-driven society (Levy-Feldman and Libman 2022Abisoye, 2023). Implementation of AI concepts and digital tools remains inconsistent, pedagogical support is limited, and digital divides continue to restrict equitable access, especially within underserved communities (Matthews et al., 2021; Xing et al., 2018). Consequently, many graduates lack the hybrid technical and human-centered competencies required for emerging roles (Richland and Simms 2015; Kučera and Haffner 2025). Nonetheless, several international examples demonstrate effective reform strategies. Finland's *Elements of AI* initiative integrates AI literacy and ethics into secondary and tertiary curricula, democratizing AI knowledge and fostering lifelong learning (Sârb, 2024). Singapore's *AI for Everyone (AI4E*) program enhances public understanding of AI technologies and their societal implications, embedding ethical and interdisciplinary learning across its education system (Xu et al., 2022). Similarly, the University of Helsinki's *Elements of AI* course has achieved remarkable global reach, engaging over 750,000 learners worldwide (Heintz & Roos, 2021). These examples illustrate the transformative potential of context-specific initiatives while underscoring the need for systemic reforms that connect AI literacy with ethical reasoning, civic responsibility, and workforce adaptability.

Addressing the structural limitations of current education models requires a paradigm shift in curriculum design, delivery, and assessment. Reforms should prioritize adaptability, critical thinking, creativity, and interdisciplinary collaboration (George & George, 2024). Embedding AI literacy across the educational continuum is fundamental to this transformation. Early exposure through project-based and gamified learning fosters curiosity and digital confidence from the primary level (Efstratopoulou et al., 2024; Ruziyevna, 2025). At the secondary level, integrating programming, data science, and ethics enables students to grasp both the technical and societal dimensions of AI. In higher education, cross-disciplinary curricula ensure graduates develop foundational AI fluency, while community-based programs such as AI boot camps and digital literacy workshops extend access to marginalized groups, promoting inclusivity and equity (Akgun & Greenhow, 2022; Zhang et al., 2023). Beyond technical proficiency, effective reform must cultivate soft skills, ethical awareness, and interdisciplinary perspectives. Combining AI education with training in communication, creativity, collaboration, empathy, and ethical reasoning prepares learners for complex real-world contexts (George, 2023). Pedagogical approaches such as project-based learning, case studies, and role-based simulations reinforce the connection between theory and practice. Integrating STEM with the humanities and social sciences encourages holistic, context-sensitive thinking that supports socially responsible and human-centred innovation (Leon et al., 2025). Ultimately, holistic and inclusive educational reforms that embed AI literacy, faculty development, flexible learning, and cross-sector collaboration will enhance innovation, equity, and resilience in the AI era. Such transformations align with social constructivist and transformative learning principles, promoting learners who are not only technologically adept but also ethically grounded and socially responsive.

Strategies for upskilling and reskilling in an AI-driven economy

The rapid advancement of AI and digital technologies requires workers to continuously upskill and reskill, emphasizing adaptability, cross-functional collaboration, and ethical awareness to remain employable. Workforce development must shift toward flexible, learner-centered ecosystems that support lifelong and modular learning. Governments, industries, and educational institutions play a crucial role in promoting agile skill development, thereby ensuring inclusive participation in the digital economy. Key elements for a future-oriented workforce strategy include vocational and professional pathways, lifelong learning models, and institutional enablers.

Vocational and professional training pathways are central to equipping individuals with industry-relevant skills through practical, hands-on learning. Modern vocational education and training (VET) systems increasingly integrate digital skills, data literacy, and AI fundamentals, as exemplified by Germany and Singapore's dual education models (Pedro et al., 2019; Xinming, 2023). Similarly, professional training programs in the private sector leverage in-house learning platforms, AI-driven microlearning modules, and certification pathways to address skill gaps, enhance organizational resilience, and promote innovation and knowledge-sharing cultures (Lee and Tan 2023). These initiatives enable rapid, applied skill development aligned with real-time labor market needs.

Lifelong learning and flexible delivery models Further support continuous skill development. Individuals must learn, unlearn, and relearn throughout their careers, facilitated by flexible platforms such as online courses, micro-credentials, and AI-enhanced adaptive learning systems that tailor content to learners' competencies and goals (Dritsas & Trigka, 2025; Niyomves et al., 2024). Employers increasingly embed lifelong learning into performance frameworks through mentorship, rotational programs, and continuous learning incentives. At the policy level, initiatives like the European Union's Upskilling Pathways and UNESCO's inclusive education frameworks provide support for vulnerable populations, bridging digital divides and fostering equitable access to skill-building opportunities (Jagannathan, 2021; Mustafa & Lleshi, 2024).
Institutional enablers of effective reskilling ecosystems involve coordinated multi-stakeholder approaches, including educational institutions, employers, government agencies, and civil society. Essential elements include aligning curricula with labour market demands, offering modular and stackable credentials, promoting cross-sector partnerships for co-designed training and work-integrated learning, investing in digital infrastructure, and providing policy incentives such as subsidies and recognition frameworks (Alenezi et al., 2024; Diaz & Halkias, 2021). These enablers facilitate scalable, inclusive, and adaptive reskilling systems. Investing in upskilling and reskilling is critical for economic sustainability and social inclusion in the AI era. Integrating these strategies into education and labour policies promotes innovation, addresses skill mismatches, and empowers individuals to thrive in a rapidly evolving digital landscape.

Policy and practice implications

Systemic policy interventions are crucial for bridging the gap between education and the evolving world of work, thereby ensuring equitable access to transformative learning experiences. As AI and digital technologies reshape labor markets, aligning educational systems with emerging workforce needs requires strategies that promote industry-aligned learning, inclusive AI education, and ethical governance.

Equitable access to AI education is critical for social justice and economic inclusion. Policies should target marginalized groups, including women, low-income communities, and ethnic minorities, through scholarships, community digital hubs, and culturally responsive curricula. Inclusive AI education also requires addressing algorithmic bias, representation, and cultural responsiveness (Chang, 2019; Farahani & Ghasemi, 2024; Oyetade & Zuva, 2025). Additionally, Teacher training initiatives, global best practices, and national strategies integrating accessibility, affordability, and diversity into AI literacy programs further support equitable participation (Gabriel et al., 2022; Oyetade & Zuva, 2025). Collectively, such strategies promote workforce resilience, innovation, and equitable development, positioning AI-enhanced education systems as inclusive and future-ready ecosystems.

Effective AI integration requires strong regulatory frameworks to safeguard data privacy, protect learners' rights, and ensure transparency in AI-driven assessments. Institutional readiness must extend beyond individual training to include supportive infrastructure, leadership capacity, and coherent policies. Universities adopting AI-enabled learning management systems benefit from governance structures, clear data policies, and collaborative faculty networks that sustain innovation (Nguyen et al., 2023; Pedro et al., 2019). Also, interdisciplinary collaboration and communities of practice further strengthen the holistic adoption of AI across teaching, research, and operations. Investing in inclusive, ethically grounded, and well-supported AI education policies ensures that technological advancements translate into meaningful learning experiences (Oyetade & Zuva, 2025; Ratner et al., 2025). By institutionalizing public-private partnerships, embedding AI literacy and ethics across curricula, and expanding digital infrastructure, policymakers can cultivate adaptive, socially responsible, and interdisciplinary competencies (Allam et al., 2025).

Despite advances in AI integration, several systemic and psychosocial challenges hinder their full transformative potential in education, with implications for policy, pedagogy, and sustainability. For instance, the rise of micro-credentials, digital badges, and AI-driven certification platforms has raised concerns about credential inflation, the devaluation of formal qualifications due to their proliferation and variable quality. While these credentials increase access and flexibility, they can create uncertainty for learners and employers regarding their value (Shanmughan et al., 2024; Tomlinson & Watermeyer, 2022). Addressing this requires policy mechanisms that enforce standardization, recognition frameworks, and quality assurance systems to maintain credibility and ensure that emerging AI-based learning pathways are trusted and meaningful. Also, AI-powered platforms offer personalized learning experiences, yet sustaining learner motivation remains a challenge, particularly in self-paced, algorithm-driven environments. Over-reliance on automated feedback can diminish intrinsic motivation if learners perceive reduced human connection or purpose (Raaj 2025; Mohebbi, 2025). Effective AI integration

should strike a balance between personalization and social interaction, collaborative activities, and meaningful human feedback, reflecting the principles of Social Constructivism, to enhance engagement and promote deeper, more reflective learning (Mishra, 2023; Richter et al., 2024).

The pervasive use of digital tools and AI-mediated instruction can also contribute to digital fatigue, marked by cognitive overload, reduced concentration, and burnout among learners and educators (Chong et al., 2025). While consistent with connectivist learning environments, constant connectivity and information abundance can undermine well-being and retention if not managed effectively. Mitigation strategies include structured offline reflection, blended learning models, and the mindful use of technology to promote cognitive recovery and sustained engagement (Kamalabai et al., n.d.; Krishna & Rajan, 2025). Collectively, these challenges highlight that AI integration is not purely technological but fundamentally human-centred. Ethical governance, emotional intelligence, and careful pedagogical design are crucial to ensuring that AI-enhanced education remains sustainable, inclusive, and learner-centred. Recognizing and addressing credential inflation, motivation, and digital fatigue enables the development of resilient educational ecosystems that can prepare learners for the demands of the AI era.

Discussion

The findings underscore the urgent need for education systems to evolve from rigid, industrial-age structures to adaptive, inclusive, and ethically grounded ecosystems that can prepare learners for the gAI era. Anchored in connectivism, social constructivism, and transformative learning, this discussion interprets how AI integration reshapes pedagogy, curriculum, and workforce readiness, while highlighting persistent challenges and strategic opportunities for reform.

Across literature, there is growing consensus on the core competencies essential for success in AI-driven societies, adaptability, critical thinking, AI literacy, and ethical reasoning. These competencies integrate cognitive, emotional, and social capacities that thrive through interdisciplinary and experiential learning (Challoumis, 2024; Pedro et al., 2019). From a connectivist view, learners must navigate AI-enabled networks and co-create knowledge across digital and human systems. Social constructivism reinforces collaboration and learner agency, positioning teachers as facilitators who guide inquiry and reflection. Transformative learning further deepens this by promoting ethical awareness and critical reflection when confronting AI-driven dilemmas, cultivating responsible and value-based citizenship (Kayal, 2024; Mukhlis et al., 2024).

Despite recognition of these emerging needs, many education systems remain underprepared. Persistent barriers, limited AI integration across curricula, inadequate teacher training, and reliance on rote and siloed instruction, continue to impede meaningful reform. Inadequate AI literacy perpetuates digital exclusion, while standardized assessments constrain creativity and ethical inquiry (Chowdhury et al., 2024; George & George, 2024). To counter this, education reform must prioritize modular and practice-based learning pathways that bridge theory and application, nurture curiosity, and link technological proficiency with humanistic and ethical reflection. Key competencies and recommendations are provided in Table 2.

Table 2. Key Competencies and Policy Recommendations for Future-Ready Education in the gAI Era

Focus Area	Key Competencies / Strategies	Policy Recommendations / Implementation Actions	Theoretical Link
Foundational AI Literacy	Understanding AI concepts, algorithmic processes, and data ethics	Integrate AI literacy into curricula across all levels; promote public AI awareness campaigns	Connectivism
Critical Thinking and Ethical Reasoning	Evaluating AI-generated outputs, addressing bias, and making responsible decisions	Embed ethics, philosophy, and digital citizenship modules in all academic programs	Transformative learning
Adaptability and Lifelong Learning	Flexibility, self-directed learning, and openness to technological change	Support modular and micro-credentialed learning pathways for continuous reskilling	Connectivism & transformative learning

(*Continued*)

Table 2. (Continued)

Focus Area	Key Competencies / Strategies	Policy Recommendations / Implementation Actions	Theoretical Link
Interdisciplinary and Human-Centred Skills	Collaboration, empathy, creativity, and communication	Encourage curriculum integration across STEM, humanities, and social sciences	Social constructivism
Teacher Capacity and Pedagogical Innovation	Use of AI tools to support inquiry-based and personalized learning	Fund professional development and provide institutional incentives for AI integration in teaching	Social constructivism
Inclusivity and Equity in AI Education	Digital access, cultural responsiveness, and social justice orientation	Implement targeted initiatives for underserved communities and promote equitable access to AI infrastructure	Transformative learning
Ethical Governance and Accountability	Transparency, privacy protection, and responsible data management	Develop policies ensuring fairness, data security, and human oversight in AI use within education	Transformative learning & connectivism

Emerging practices illustrate how these transformations can take shape. AI-integrated curricula embed ethical reasoning and data literacy across disciplines; blended learning models combine technical and soft-skill development; and lifelong learning frameworks employ personalized AI platforms and micro-credentials to support continuous upskilling (Challoumis, 2024; Niyomves et al., 2024). These innovations, rooted in connectivist and transformative principles, promote learner autonomy, networked knowledge, and equitable participation, cornerstones of socially responsible AI education. Yet, integrating gAI also introduces ethical and equity challenges, algorithmic bias, surveillance, and data privacy, which require deliberate governance. Inclusive AI education must ensure equitable access to infrastructure, diversify representation in curriculum design, and embed cultural and ethical responsiveness (Oyetade & Zuva, 2025). This aligns with Transformative Learning by empowering learners to question dominant narratives and advocate for justice-oriented innovation.

To operationalise these directions, a phased, collaborative roadmap is proposed, assigning roles to government, institutions, industry, and civil society while ensuring adaptability to diverse national contexts.

- **Phase 1: Assessment (0–12 Months):** Establish a national AI-in-education task force to audit digital readiness, teacher capacity, and equity gaps, and to define baseline indicators.
- **Phase 2: Pilot (12–36 Months):** Implement AI-literacy modules, professional-development programs, and institutional data-governance protocols through pilot sites.
- **Phase 3: Scale (36–72 Months):** Integrate validated AI curricula into national systems, standardize quality assurance for micro-credentials, and institutionalize funding for lifelong learning.
- **Phase 4: Sustain (Ongoing):** Conduct periodic evaluations, refine curricula, and sustain multi-stakeholder governance through transparent review cycles.

Stakeholder roles include:

- *Government*: define strategy, incentives, and legal frameworks.
- *Institutions*: implement curricula, evaluate outcomes, and support educators.
- *Industry*: co-design competencies and offer work-integrated learning.
- *Civil Society & Learners*: ensure cultural relevance and monitor equity impact.
- *Accreditation Bodies*: maintain standards and recognition frameworks.

Operational principles include piloting before scaling, prioritizing equity, safeguarding wellbeing, and using iterative governance to respond to technological change.

Ethical governance transforms principles of fairness and transparency into institutional practice through structured mechanisms and accountability:

- **Ethics committees & Policy frameworks**: Establish multidisciplinary AI ethics committees aligned with national data-protection laws (e.g., POPIA, GDPR) and UNESCO guidelines.

- **Transparency & Accountability**: Require explainable AI in learning analytics and assessments, with open documentation of decision logic and data sources.
- **Continuous ethical audits**: Conduct periodic impact reviews to detect bias, misuse, or inequities, informed by educator and learner feedback.
- **Capacity building:** Embed AI ethics and data stewardship in teacher-training and professional-learning programs.
- **Inclusive governance**: Engage educators, students, and marginalized communities in AI policy design to ensure cultural and contextual responsiveness.

By embedding these mechanisms, ethical governance becomes a living system of reflection, evaluation, and accountability, ensuring that AI integration in education remains human-centered, equitable, and socially responsible.

Building on the review and discussion, the study proposes five interlinked actions to align education with the gAI era: (1) embed AI literacy across all levels; (2) promote lifelong, modular learning pathways; (3) strengthen teacher capacity for ethical, AI-integrated pedagogy; (4) foster cross-sector partnerships for curriculum co-design; and (5) ensure equitable and transparent AI governance. Collectively, these actions position education as a proactive driver of ethical innovation and inclusive digital transformation.

Conclusion

The rapid evolution of gAI is reshaping work, learning, and society, demanding a profound transformation in education. Grounded in the theoretical frameworks of connectivism, social constructivism, and transformative learning, this study highlights the need for education systems to develop future-ready, ethically conscious, and adaptive learners. Beyond knowledge transmission, education must cultivate AI literacy, digital fluency, critical and ethical reasoning, and lifelong adaptability, ensuring learners can meaningfully participate in AI-driven economies and societies. While innovative practices such as interdisciplinary curricula, AI-integrated learning tools, and flexible upskilling pathways are emerging globally, persistent barriers remain, including unequal digital access, underprepared educators, and curricula misaligned with evolving labour market needs. Addressing these challenges requires systemic and strategic reforms encompassing pedagogy, policy, institutional capacity, and cross-sector collaboration. Empirical examples from Finland, Singapore, South Africa, and the European Union demonstrate how diverse contexts operationalize these reforms through scalable, ethics-oriented initiatives, emphasizing teacher training, ethical governance, and inclusive AI education.This study used a descriptive literature review, relying solely on secondary sources, which may not capture the most recent or context-specific developments in AI education. The review was limited to publications from 2015 to 2025 and focused on English-language literature, potentially overlooking relevant insights from non-English-speaking regions, especially in the Global South. Future research should include empirical studies, longitudinal analyses, and comparative case investigations to strengthen and extend these findings.

Declarations

Interdisciplinary Scope: This study takes an interdisciplinary approach that includes education, artificial intelligence, ethics, sociology, economics, and public policy. Curriculum and pedagogy are informed by educational theory, whereas AI and computer science contribute to our understanding of AI literacy and generative technologies. Fairness and accountability are addressed from an ethical and responsible computing approach. Labor market movements and inequality are examined via sociological and economic lenses, notably in the Global South. Public policy approaches contribute to an understanding of governance, institutional preparation, and cross-sector collaboration for inclusive educational transformation.

Author Contributions: Conceptualization (Oyetade), literature search (Oyetade), methodology (Oyetade), writing – original draft and final draft (Oyetade and Zuva), Writing – review & editing (Oyetade and Zuva). The final version of the article has been approved by all the authors.

Conflict of Interest: The authors have no conflict of interest to declare.

Funding: This work was supported by the South African National Research Foundation (Grant number [PSTD230531111971]. Author KE has received research support from NRF.

Availability of Data: The data that support the findings of this study can be openly accessed from multiple sources, including the websites of several organizations, publicly available reports, and indexed databases of academic journals.

References

Ajiga, D. I., Hamza, O., Eweje, A., Kokogho, E., & Odio, P. E. (2025). Developing interdisciplinary curriculum models for sustainability in higher education: A focus on critical thinking and problem solving. *Journal of Public Administration and Social Welfare Research*, *10*, 87–102.

Akgun, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. *AI and Ethics*, *2*(3), 431–440. https://doi.org/10.1007/s43681-021-00096-7

Alam, A. (2022). Mapping a sustainable future through conceptualization of transformative learning framework, education for sustainable development, critical reflection, and responsible citizenship: an exploration of pedagogies for twenty-first century learning. *ECS Transactions*, *107*(1), 9827–9840. https://doi.org/10.1149/10701.9827ecst

Alam, A. (2023). Connectivism learning theory and connectivist approach in teaching and learning: A review of literature. *Bhartiyam International Journal of Education & Research*, *12*(2), 1–15.

Alenezi, M., Akour, M., & Alfawzan, L. (2024). Evolving microcredential strategies for enhancing employability: Employer and student perspectives. *Education Sciences*, *14*(12), 1307. https://doi.org/10.3390/educsci14121307

Allam, H. M., Gyamfi, B., & AlOmar, B. (2025). Sustainable innovation: Harnessing AI and living intelligence to transform higher education. *Education Sciences*, *15*(4), 398. https://doi.org/10.3390/educsci15040398

Alrassi, J., Katsufrakis, P. J., & Chandran, L. (2021). Technology can augment, but not replace, critical human skills needed for patient care. *Academic Medicine*, *96*(1), 37–43. https://doi.org/10.1097/ACM.0000000000003733

Amankwah-Amoah, J., Abdalla, S., Mogaji, E., Elbanna, A., & Dwivedi, Y. K. (2024). The impending disruption of creative industries by generative AI: Opportunities, challenges, and research agenda. *International Journal of Information Management*, *79*, 102759. https://doi.org/10.1016/j.ijinfomgt.2024.102759

Asrifan, A., Said, U. M. R., Jakob, J. C., & Wanci, R. (2025). AI literacy: Foundations, importance, and broader implications. In *Transforming vocational education and training using AI* (pp. 17–48). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-8252-3.ch002

Burton, S. L. (2024). Advancements in AI-driven education: Transforming learning and training with intelligent technologies. *World Journal of Business Research*, *4*(1), 9.

Cain, K., & Coldwell-Neilson, J. (2024). Digital fluency – A dynamic capability continuum. *Australasian Journal of Educational Technology*, *40*(1), 42–56. https://doi.org/10.14742/ajet.8363

Callari, T. C., Vecellio Segate, R., Hubbard, E.-M., Daly, A., & Lohse, N. (2024). An ethical framework for human-robot collaboration for the future people-centric manufacturing: A collaborative endeavour with European subject-matter experts in ethics. *Technology in Society*, *78*, 102680. https://doi.org/10.1016/j.techsoc.2024.102680

Challoumis, C. (2024). In *The imperative of skill development in an AI revolution*. [XIX International Scientific Conference. London. Great Britain].

Chang, E. (2019). Bridging an engagement gap: Towards equitable, community-based technology leadership practice. *International Journal of Leadership in Education*, *22*(5), 536–554. https://doi.org/10.1080/13603124.2018.1492504

Chong, S.-E., Looi, K. H., & Shahudin, F. (2025). Beyond the prompt: Exploring technostress, flow and personality in generative AI behaviors. *The Electronic Library*, *43*(5), 733–756. https://doi.org/10.1108/EL-05-2025-0171

Chowdhury, S. A., Dey, M., & Cross, B. (2024). Rethinking education in the era of fourth industrial revolution (4IR): Perspective of less developed countries. In A. N. Lee & Y. Nie (Eds.), *Future-oriented learning and skills development for employability: Insights from singapore and some asia-pacific contexts* (pp. 35–52). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-8584-1_3

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). *21st century skills development through inquiry-based learning from theory to practice*. Springer.

Diaz, J., & Halkias, D. (2021). Reskilling and upskilling 4IR leaders in business schools through an innovative executive education ecosystem: An integrative literature review. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3897059

Dritsas, E., & Trigka, M. (2025). Methodological and technological advancements in e-learning. *Information*, *16*(1), 56. https://doi.org/10.3390/info16010056

Efstratopoulou, M., Shraim, Z., & Saleh, H. (2024). Empowering all students: Revolutionizing education with gamification, project-based learning, and inclusive support. In *Cutting-edge innovations in teaching, leadership, technology, and assessment* (pp. 54–67). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-0880-6.ch005

Farahani, M., & Ghasemi, G. (2024). Artificial intelligence and inequality: Challenges and opportunities. *International Journal of Innovation in Education*, *9*, 78–99.

Gabriel, F., Marrone, R., Van Sebille, Y., Kovanovic, V., & de Laat, M. (2022). Digital education strategies around the world: Practices and policies. *Irish Educational Studies*, *41*(1), 85–106. https://doi.org/10.1080/03323315.2021.2022513

George, A. S. (2023). Preparing students for an AI-driven world: Rethinking curriculum and pedagogy in the age of artificial intelligence. *Partners Universal Innovative Research Publication*, *1*(2), 112–136.

George, A. S., & George, A. H. (2024). Towards a super smart society 5.0: Opportunities and challenges of integrating emerging technologies for social innovation. *Partners Universal International Research Journal*, *3*(2), 01–29.

Heintz, F., & Roos, T. (2021). Elements of AI-teaching the basics of AI to everyone in Sweden. *EDULEARN21 Proceedings*. https://doi.org/10.21125/edulearn.2021.0559

Ibegbulam, C., Olowonubi, J., Fatounde, S., & Oyegunwa, O. (2023). Artificial intelligence in the era of IR: Drivers, challenges and opportunities. Engineering Science & Technology Journal, *4*(6), 473–488. https://doi.org/10.51594/estj.v4i6.668

Jagannathan, S. (2021). *Reimagining digital learning for sustainable development: How upskilling, data analytics, and educational technologies close the skills gap*. Routledge. https://doi.org/10.4324/9781003089698

Johan, J., Kartono, R., Hamsal, M., & Furinto, A. (2023). The influence of creative & critical thinking and collaboration on digital & technology fluency. *E3S Web of Conferences*, *426*, 02144. https://doi.org/10.1051/e3sconf/202342602144

Kamalabai, P. S., Mathew, A., Michael, A., Jose, S., & Babu, S. (n.d.). Virtual happiness and its implications to the higher education sector. In *Holistinis požiūris į kolegijinių studijų perspektyvą visuomenės, darbo rinkos ir aukštojo mokslo sistemos kaitos kontekste* (pp. 61–84). Šv. Ignaco Lojolos Kolegija.

Kayal, A. (2024). Transformative pedagogy: A comprehensive framework for AI integration in education. In T. Singh, S. Dutta, S. Vyas, & Á. Rocha (Eds.), *Explainable AI for education: Recent trends and challenges* (pp. 247–270). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-72410-7_14

Kayyali, M. (2024). Future possibilities and challenges of AI in education. In *Transforming education with generative AI: Prompt engineering and synthetic content creation* (pp. 118–137). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-1351-0.ch006

Krishna, M. S., & Rajan, G. (2025). Virtual fatigue, real solutions. In *Addressing digital fatigue and reclaiming well-being in the era of online learning for college students. Digital pedagogy* (p. 7).

Kučera, E., & Haffner, O. (2025). *Competency-based hybrid learning: A modern approach to teaching programming and digital technologies subjects*. IEEE Access. https://doi.org/10.1109/ACCESS.2025.3555333

Lai, C.-J. (2025). Evaluating generative AI-assisted inquiry-based learning and metacognitive scaffolding for enhancing scientific vocabulary, content comprehension, and lab report writing. *Interactive Learning Environments*, 1–15. https://doi.org/10.1080/10494820.2025.2572786

Lee, W. C., & Tan, B. C. Y. (2023). Workplace learning strategies, enablers, and challenges in the context of digital innovation. *Journal of Workplace Learning*, *35*(2), 192–209. https://doi.org/10.1108/JWL-04-2022-0045

Leon, C., Lipuma, J., & Oviedo-Torres, X. (2025). Artificial intelligence in STEM education: A transdisciplinary framework for engagement and innovation. *Frontiers in Education*, *10*. https://doi.org/10.3389/feduc.2025.1619888

Levy-Feldman, I., & Libman, Z. (2022). One size *doesn't* fit all educational assessment in a multicultural and intercultural world. *Intercultural Education*, *33*(4), 380–390. https://doi.org/10.1080/14675986.2022.2090174

Long, D., & Magerko, B. (2020). In *What is AI literacy? Competencies and design considerations*. [Proceedings of the 2020 CHI conference on human factors in computing systems].

Luckin, R. (2025). Nurturing human intelligence in the age of AI: Rethinking education for the future. *Development and Learning in Organizations*, *39*(1), 1–4. https://doi.org/10.1108/DLO-04-2024-0108

Matthews, A., McLinden, M., & Greenway, C. (2021). Rising to the pedagogical challenges of the Fourth Industrial Age in the university of the future: An integrated model of scholarship. *Higher Education Pedagogies*, *6*(1), 1–21. https://doi.org/10.1080/23752696.2020.1866440

Mishra, N. R. (2023). Constructivist approach to learning: An analysis of pedagogical models of social constructivist learning theory. *Journal of Research and Development*, *6*(1), 22–29. https://doi.org/10.3126/jrdn.v6i01.55227

Mohebbi, A. (2025). Enabling learner independence and self-regulation in language education using AI tools: A systematic review. *Cogent Education*, *12*(1), 2433814. https://doi.org/10.1080/2331186X.2024.2433814

Mukhlis, H., Haenilah, E. Y., Maulina, D., & Nursafitri, L. (2024). Connectivism and digital age education: Insights, challenges, and future directions. *Kasetsart Journal of Social Sciences*, *45*(3). https://doi.org/10.34044/j.kjss.2024.45.3.11

Mustafa, B., & Lleshi, S. (2024). The impact of lifelong learning and investments in employee development on employee productivity and performance. *Multidisciplinary Reviews*, *7*(8), 2024175. https://doi.org/10.31893/multirev.2024175

Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education*, *2*, 100041. https://doi.org/10.1016/j.caeai.2021.100041

Nguyen, A., Ngo, H. N., Hong, Y., Dang, B., & Nguyen, B.-P. T. (2023). Ethical principles for artificial intelligence in education. *Education and Information Technologies*, *28*(4), 4221–4241. https://doi.org/10.1007/s10639-022-11316-w

Niyomves, B., Kunacheva, N., & Kenaphoom, S. (2024). The role of lifelong learning in navigating the future of work. In *Modern management science practices in the age of AI* (pp. 297–316). IGI Global. https://doi.org/10.4018/979-8-3693-6720-9.ch011

Olaniyi, O. O., Ezeugwa, F. A., Okatta, C., Arigbabu, A. S., & Joeaneke, P. (2024). Dynamics of the digital workforce: Assessing the interplay and impact of AI, automation, and employment policies. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4806307

Oyetade, K., & Zuva, T. (2025). Advancing equitable education with inclusive AI to mitigate bias and enhance teacher literacy. *Educational Process: International Journal*, *14*, e2025087.

Oyetade, K., Zuva, T., & Harmse, A. (2025). Integrating Industry 4.0 technologies into IT education. *Cogent Education*, *12*(1), 2479195. https://doi.org/10.1080/2331186X.2025.2479195

Pedro, F., Subosa, M., Rivas, A., & Valverde, P. (2019). In *Artificial intelligence in education: Challenges and opportunities for sustainable development*. [UNESCO Working Papers on Education Policy No. 7].

Raaj, J. (2025). AI-Powered Learning: Revolutionizing Student Assessment. *International Journal of Research and Innovation in Applied Science*, *X*(V), 583–587. https://doi.org/10.51584/IJRIAS.2025.100500052

Rane, N. (2023). ChatGPT and similar generative artificial intelligence (AI) for smart industry: Role, challenges and opportunities for Industry 4.0, Industry 5.0 and Society 5.0. *SSRN Electronic Journal*, *4*. https://doi.org/10.2139/ssrn.4603234

Ratner, S., Williams, R., & Wonnacott, E. (2025). In *Exploring AI in education through interdisciplinary collaboration*. [INTED2025 Proceedings].

Rezaei, M., Pironti, M., & Quaglia, R. (2025). AI in knowledge sharing, which ethical challenges are raised in decision-making processes for organisations? *Management Decision*, *63*(10), 3369–3388. https://doi.org/10.1108/MD-10-2023-2023

Richland, L. E., & Simms, N. (2015). Analogy, higher order thinking, and education. *Wiley Interdisciplinary Reviews. Cognitive Science*, *6*(2), 177–192. https://doi.org/10.1002/wcs.1336

Richter, S., Giroux, M., Piven, I., Sima, H., & Dodd, P. (2024). A constructivist approach to integrating AI in marketing education: Bridging theory and practice. *Journal of Marketing Education*, *47*(2), 94–111. https://doi.org/10.1177/02734753241288876

Ruziyevna, M. M. (2025). The effectiveness of using innovative methods in primary education. *Spanish Journal of Innovation and Integrity*, *47*, 21–28.

Sârb, C. (2024). Digital Education Evolution: Investigating Finland's past and future directions.

Shanmughan, P., Joseph, J., BN, S., A., S.M., A, C.S., & Jose, J. (2024). The AI revolution in micro-credentialing: personalized learning paths. *Frontiers in Education*, *9*.

Tomlinson, M., & Watermeyer, R. (2022). When masses meet markets: Credentialism and commodification in twenty-first century Higher Education. Discourse: Studies in the Cultural Politics of Education, *43*(2), 173–187. https://doi.org/10.1080/01596306.2020.1814996

Xing, B., Marwala, L., & Marwala, T. (2018). Adopt fast, adapt quick: Adaptive approaches in the South African context. In *Higher education in the era of the fourth industrial revolution* (pp. 171–206). Springer Singapore Singapore. https://doi.org/10.1007/978-981-13-0194-0_8

Xinming, Z. (2023). Research on cultivating innovation and practical skills in higher vocational education. *Frontiers in Educational Research*, *6*(26). https://doi.org/10.25236/FER.2023.062606

Xu, P., Dong, W., & Wang, C. (2022). Present situation and enlightenment of artificial intelligence lifelong education system in Singapore. *Journal of Autonomous Intelligence*, *5*(1), 23. https://doi.org/10.32629/jai.v5i1.499

Zhang, H., Lee, I., Ali, S., DiPaola, D., Cheng, Y., & Breazeal, C. (2023). Integrating ethics and career futures with technical learning to promote AI literacy for middle school students: An exploratory study. *International Journal of Artificial Intelligence in Education*, *33*(2), 290–324. https://doi.org/10.1007/s40593-022-00293-3