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ARTIFICIAL INTELLIGENCE AND THE FUTURE OF EDUCATION SYSTEMS: A COMPREHENSIVE REVIEW OF OPPORTUNITIES, CHALLENGES, AND EMERGING TRENDS

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ABSTRACT

Artificial Intelligence (AI) is a quantum leap in education technology that has the potential to revolutionize education. Artificial Intelligence (AI) is an educational technology paradigm providing unprecedented possibilities to individualize learning, improve teacher effectiveness and optimize institutional processes. This comprehensive SLR brings together the results of 70 peer-reviewed studies from various academic databases, including Scopus, Web of Science, ERIC and ScienceDirect, published during 2019-2025. The study examines multifaceted applications of AI in education, intelligent tutoring systems, adaptive learning platforms, learning analytics, and generative AI tools, like ChatGPT. While AI holds great potential to improve the learning experiences and results of students, challenges must be addressed, such as algorithmic bias, data privacy concerns, digital equity, teacher readiness and ethical governance. This review, instead of simply describing the work, recognizes key research gaps, lay the foundation for an integrated conceptual framework on how to implement AI in educational transformation, and makes recommendations grounded in evidence for policymakers, educators and technologists. The review emphasizes the importance of collaboration among stakeholders, strong ethical guidelines, professional development for educators, and the need for policies that are contextually appropriate and mitigate the global digital divide in responsible implementation of AI. Looking forward, future directions highlight the importance of conducting impact studies over time, designing AI tools with cultural sensitivity, and remaining focused on preserving human-centered education in the era of technology.

Keywords: Artificial Intelligence, education systems, intelligent tutoring systems, adaptive learning, educational technology, generative AI, ChatGPT, digital transformation, educational equity, ethical AI

1. INTRODUCTION

1.1 Global Digital Transformation of Education

There has been an unprecedented digitalization process in the global education landscape in the last 20 years, which has skyrocketed during COVID-19 pandemic (Bozkurt et al., 2020). In response to the change in teaching models from a classroom environment to a hybrid or remote format, educational institutions have had to make fast progress in the adoption of digital technologies. This basic change in how education is provided has presented opportunities and challenges to students, teachers, and policy makers (Paul et al., 2024). The use of ICTs in teaching and learning has expanded beyond being an add-on to a fundamental part of learning, transforming the approach to education, evaluation techniques and the organizational framework of schools (Gkrimpizi et al., 2023).

1.2 Rise of AI Technologies in Education

Artificial Intelligence has become a game-changer in this digital ecosystem, from academic research abstracts to its impact on millions of students across the globe (Zawacki-Richter et al., 2019). Since the early days of the 1960s, the field of Artificial Intelligence in Education (AIED) has come a long way, starting with rule-based expert systems, then moving onto machine learning methods and most recently the large language models like ChatGPT (Mahrishi et al., 2024). The public release of ChatGPT in November 2022 was a turning point that has garnered

unprecedented attention from the mainstream media, resulting in a surge of interest in the education-oriented applications of AI and raising the need for discussions on its implications for teaching, learning, and assessment (Lo, 2023). This rapid change has outpaced the capacity of institutions to reflect on and design policies in meaningful ways, thus leading to an environment of both need for urgent opportunities and real risk (Sadler et al., 2024).

1.3 Significance of AI in Teaching and Learning

AI-based educational technologies have been proven to have significant potential for solving common teaching problems (Suntharalingam, 2024). These systems can create individualized learning paths, offer immediate support that adapts to students' needs, free up teachers' time by automating repetitive activities, and analyze complex educational data to produce insights (Ayeni et al., 2024). AI has the promise to empower disadvantaged groups such as students from low-resource areas and those with disabilities, potentially leveling the playing field for quality education (Han & Kumwenda, 2024). There is a need, however, to consider the possibility of imbalance with regard to equity, transparency, and the maintenance of key human aspects in education (Avraamidou, 2024).

1.4 Research Problem and Rationale

While teachers have increasingly embraced AI in the classroom, there are some key areas in which we need to better understand its effects and best practices for application (Zawacki-Richter et al., 2019). Current research tends to examine technical skills and performance, and fail to look at broader measures of educational outcomes, equity considerations, and the long-term impact on learning (Holmes et al., 2021). There is a worrying mismatch between the development of AI and the needs for implementation in settings of poverty and deprivation (Alami et al., 2020). In addition, the ethical standards for the use of AI in education are underdeveloped, and teacher training for the integration of AI into the pedagogical field is still very low (Nyaaba & Zhai, 2024). The gaps inspired this thorough review, aimed at consolidating existing evidence, outlining key research gaps, and proposing practical approaches to the responsible use of AI in education.

1.5 Research Objectives

This review aims at seven main objectives:

1. To systematically synthesize empirical and theoretical literature for the use of AI in education from 2019-2025.
2. To identify and critically analyze opportunities AI can provide for improving learning outcomes, access and equity in education.
3. To explore content issues and threats of implementing AI in educational settings.
4. To assess the new trends of Generative Artificial Intelligence, specifically Large Language Models and their implications in education.
5. To measure the geographic variability and cultural specificity of use of AI in various educational systems
6. To build a comprehensive conceptual framework that connects AI technologies, learning processes, and social effects.
7. To pinpoint key research needs and to suggest a research agenda based on existing evidence.

1.6 Research Questions

The review considers seven general research questions:

RQ1: What are the primary categories of AI applications being implemented in educational settings globally, and what evidence exists for their effectiveness?

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RQ2: What are the effects of AI-powered educational interventions on measurable learning outcomes, student engagement and educational equity?
RQ3: What are some of the major challenges and risks that arise from the use of AI in education and who might be at risk for harm?
RQ4: How is teachers prepared for the introduction of AI in teaching and what are the more effective professional development models?
RQ5: What ethical, legal, and policy frameworks are in place to regulate the use of AI in education and what are the missing areas that need attention?
RQ6: What is the impact of geopolitical context, resource availability and cultural factors on the implementation and impacts of AI in various regions?
RQ7: What are the most pressing future research needs and practical practices to make responsible, equitable AI-enabled education possible?

1.7 Scope and Contribution

The purpose of this review is to draw attention to critical synthesis rather than descriptive summary by considering the findings of the research as well as the limitations of the method, contradictions in the research, and the lack of full evidence. The paper is balanced in its approach to the potential and role of AI in education and is not apathetic in understating its significant, but real, risks and challenges. Importantly, this review focuses on global views, and explicitly highlights the relevance of this review to developing countries and the Global South, given that much economic scholarship reflects the priorities of well-resourced institutions in North America and Europe (Han & Kumwenda, 2024). The review not only considers analysis in the light of existing theory but also builds on theoretical frameworks to create new conceptual models that tie the implementation of AI technologies to learning processes and their final impact on learning results and on the broader society.

2. METHODOLOGY

2.1 Review Design

The method used in this systematic literature review was a comprehensive method that combines the elements of evidence synthesis, thematic analysis and critical realist methodology (Yan et al., 2023). The design focused on finding patterns, contrasts, and holes in a massive set of peer-reviewed articles, but not on meta-analysis of quantified effects. This was appropriate, as AI educational research is diverse – involving multiple methodologies, populations, contexts, and outcome measures.

2.2 Database Selection

Research was carried out in six significant academic databases in education, technology and interdisciplinary studies:

1. The Scopus database is a powerful, comprehensive, multidisciplinary database that heavily covers computer science, educational technology and engineering literature.
2. Specialized citation index, high quality requirements and social sciences / STEM strong coverage, Web of Science.
3. The ERIC is a specialized education research database operated by the U.S. Department of Education.
4. ScienceDirect provides access to comprehensive, scientific and technical content from a variety of fields.
5. Springer is one of the leading academic publishers in the field of AI and computer science, boasting a wide range of journals.

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2.3 Search Strategy and Keywords

The search strings were gradually refined and evaluated in various databases. Primary search strategies included Boolean operators and truncation to find appropriate variations:

Primary Search Strings: - ("artificial intelligence" OR AI OR "machine learning" OR "deep learning" OR "large language models" OR ChatGPT OR "generative AI") AND (education OR learning OR teaching OR school OR university OR "higher education") - ("intelligent tutoring system" OR "adaptive learning" OR "personalized learning") AND (AI OR "artificial intelligence") - ("learning analytics" OR "educational data mining") AND (artificial intelligence OR machine learning) - (ChatGPT OR "generative AI" OR "large language model") AND (education OR pedagogy OR teaching OR learning) - (AI OR "artificial intelligence") AND (equity OR access OR disadvantage OR inclusion OR developing countries) - (AI OR "artificial intelligence") AND (education AND (ethical OR bias OR privacy OR "data protection" OR governance))

Only peer-reviewed articles, conference proceedings and grey literature (international organisation reports, government reports) were searched. All searches were limited to English language. The time period was limited to 2019-2025, focusing on the most recent era which is dominated by neural network approaches and large language models.

2.4 Inclusion and Exclusion Criteria

Exclusion Criteria: - Secondary analysis of existing studies - Books, book chapters, or other materials not published in a journal article or conference proceedings - Not empirical, theory, or systematic review studies - Not much engagement with AI technology (other than incidental use) - Not available in English.

Exclusion Criteria: - Non-peer-reviewed opinion pieces or editorials (except by well-known scholars dealing with specific gaps) - Studies focusing exclusively on AI in contexts outside of education (e.g., studies on AI in healthcare without educational component) - Literature published prior to 2020 (to ensure focus on recent developments after neural network advances) - Studies describing AI systems (but not analyzing its implementation or impact in the field of education) - Duplicate publications or different presentation of the same dataset.

3. THEORETICAL FOUNDATIONS

3.1 Technology Acceptance Model (TAM) and Extended Models

Davis (1989) and later Davis et al. (2012) implemented the UTAUT2 (Davis et al., 1989) to include additional factors that influence AI tool acceptance and use by educators and students (Zawacki-Richter et al., 2019). The TAM suggests that the adoption of technology depends on the usefulness of the technology and the ease of use. External factors, such as institutional support and training, affect these perceptions. AI education studies on the use of TAM have found that the factors of demonstrated usefulness (Does this really enhance learning?), pedagogical fit (Does this fit with my educational philosophy?), and trust in the system reliability are critical for both teachers and students to accept AI (Arvin et al., 2023).

The Unified Theory of Acceptance and Use of Technology (UTAUT) model is an extension of TAM that additionally considers four factors: performance expectancy, effort expectancy, social influence and facilitating conditions as determinants of technology adoption (Adel, 2024a). When it comes to AI in education, it is also important to keep in mind that adoption is not just about personal perceptions but about organizational culture, peer influence, institutional commitment of resources and perceived alignment with educational values.

3.2 Diffusion of Innovation Theory

Rogers' Diffusion of Innovation Theory provides an understanding of the diffusion process of new technologies in populations and organizations and the pattern of their adoption (Zawacki-

Richter et al., 2019). This model classifies adopters into five groups: the innovators, early adopters, early majority, late majority and laggards, each having different characteristics with respect to the timing of their adoption and their needs. In the current landscape of AI's presence in educational contexts, there are clear distinctions between innovators and early adopters, typically found in higher-resourced institutions in high-income nations, and in schools in lower-income countries where adoption is still in the awareness phase (Han & Kumwenda, 2024). The knowledge of the dynamics of diffusion helps in planning more effective policy and support interventions.

3.3 Constructivist Learning Theory and AI Alignment

Some AI educational applications are compatible with constructivist approaches that focus on student-centred learning, co-construction of knowledge and scaffolding of higher order thinking skills, while others are not (Kamalov et al., 2023). Adaptive learning systems that adapt to learner performance, offer intelligent scaffolding, and facilitate discovery learning are in line with constructivist principles. On the other hand, systems that merely deliver content or limit learning to multiple-choice tests might clash with constructivism's emphasis on meaningful learning by constructing knowledge. Deliberate pedagogical design is needed for critical implementation in order to guarantee that AI complements and does not replace constructivistic interaction.

3.4 Connectivism and Distributed Learning Networks

Theories of distributed learning environments like connectivism, which highlight learning through networked participation and knowledge spread across systems and communities, offer valuable insights to inform the discussion of AI's impact in such learning contexts (Thorne, 2024). AI systems that enable peer connections, aggregation of collective knowledge and participation across networks are aligned with connectivist principles. But algorithmic-mediated curation of connections does have potential for epistemic echo chambers and less exposure to heterodox views.

3.5 Human-Centered AI Framework

Human centered-AI framework focuses on human values, agency and wellbeing in the design and deployment of AI systems (Garibay et al., 2023). Such a perspective, gaining more traction in the education sector, requires us to think about how AI can be used to support human flourishing, not to replace human relationships and human optimization of learning. Humans have control and influence over their actions and over outcomes of system processes (human agency and oversight); systems should not perpetuate or amplify inequities (diversity, non-discrimination); stakeholders should understand how the system works (transparency); clear responsibility for system outcomes and harms (accountability).

4. CONCEPTUALIZATION OF AI IN EDUCATION

4.1 Defining Artificial Intelligence

AI is defined for educational purposes as computational systems that are able to execute tasks that would normally be done by the human brain, such as perception, reasoning, learning, and decision-making (Hwang et al., 2020). Widely interpreted, it includes a range of technologies such as rule-based expert systems, machine learning algorithms that learn from data, deep learning neural networks that analyze complex patterns, and large language models that create human-like text. Educational AI applications can be categorized along this continuum, from simple applications that use algorithms based on a fixed logic (such as an algorithmic tutor) to complex applications with neural networks that recommend content or assess students.

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4.2 Evolution of AI in Education

Advancements in education technology are paralleled by the trajectory of AI in the field of education (Zawacki-Richter et al., 2019). Widely used in early systems from 1960s to 1980s, rule-based logic was used to model expert tutoring in narrow domains. In the 1990s to 2000s, the use of machine learning methods led to the development of systems that can adapt to students' interaction patterns. Deep learning and big data analytics were increasingly adopted in learning management systems (LMS) and predictive analytics applications, respectively, during the 2010s. The 2020s is an inflection point: the advent of large language models and generative AI has vastly broadened the possibilities for education through AI, as well as posing pressing questions of authenticity, academic integrity, and educational purpose.

4.3 Generative AI and Large Language Models

In the field of AI in education, generative AI systems are a qualitative leap from more traditional models, especially transformer-based architectures, such as GPT-3, GPT-4, and other contenders.Generative AI systems, and transformer-based large language models in particular, such as GPT-3, GPT-4, and other contenders, mark a shift in the nature of AI applications in education (Roumeliotis & Tselikas, 2023). These models, which are trained on huge amounts of text, can produce very human-like answers to open-ended questions, explain complicated passages or difficult concepts, summarize lengthy texts, offer feedback on students' work and help with content production. Public interfaces (ChatGPT, Bard, Claude) are accessible and easy-to-use, and do not require specialized technical skills that are traditionally used in education, which is why they can be readily used by educators and students without significant preparation (Lo, 2023).

4.4 Machine Learning and Algorithmic Personalization

Machine learning can be used to detect patterns in student performance and tailor instruction to them (Ayeni et al., 2024). Instead of going through the same paths, machine learning systems tailor the difficulty, pacing, feedback type, and content sequence to the student's characteristics. They are the approaches that support adaptive learning platforms that are gaining traction in K-12 and higher education (Gligorea et al., 2023). Data quality, algorithm design and the match of algorithmic optimization goals and actual educational goals are key factors in effectiveness.

4.5 Deep Learning and Complex Pattern Recognition

In highly complex and high-dimensional data, deep learning neural networks are highly suitable for pattern recognition, a capability that can be used for face recognition, image recognition, natural language understanding, and more (Secinaro et al., 2021). Deep learning is used in an educational environment to recommend content to students, automatically grade exams, identify student learning difficulties through temporal patterns, and analyse how students interact with video lectures. The "black box" aspect of deep learning, however, can pose concerns in an educational setting where transparency and explainability are important for student agency and trust.

4.6 Learning Analytics and Predictive Systems

Learning analytics is a field that uses data science methods to transform educational data into insights that enhance learning and teaching (Jing et al., 2023). Specifically, predictive analytics tries to predict student outcomes (chance of course failure, chance of degree completion, chances of success in a specific discipline) and therefore allows for early intervention. Predictive systems are an exciting tool to identify students who may be at-risk and need additional support, but can also be problematic because of algorithmic determinism, privacy issues, and self-fulfilling prophecies, in which students' treatment in the institution is determined by their predicted status.

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4.7 Intelligent Tutoring Systems (ITS)

Intelligent Tutoring Systems (ITSs) are among the most studied educational applications of AI, which are adaptive instructional systems that offer personalized tutoring at scale (Tafazoli et al., 2019). Effective ITs are essentially a blend of domain models (the material being taught), student models (the knowledge, preferences, learning needs of the learner), tutoring strategies (how to guide learning), and communication interfaces (Adel, 2024b). Research has shown that ITS can achieve learning gains that are similar to or superior to human tutors, especially when integrating adaptive content sequencing with meaningful interaction and feedback (Fernández-Herrero, 2024).

4.8 Adaptive Learning Platforms

Adaptive learning platforms customize the way instruction is delivered, depending on the characteristics and performance of the learner (Gligorea et al., 2023). These systems monitor student interactions, evaluate understanding through embedded assessments, uncover gaps in understanding, and adjust future instruction. The effectiveness range is very wide, depending on the sophistication of the algorithms, the quality of the evaluations, and the pedagogical quality of the adaptations. Some systems, however, get to a level of meaningful personalization, while others are shallowly adapted branching tutorials.

4.9 Educational Robotics

Educational robotics, defined as physical or virtual robots that assist in teaching and learning, is an important, but separate educational AI (eAI) category (Adel, 2024a). Robots can be used as collaborative learning partners, to help students with disabilities, to offer repeated practice with personalized feedback, or to demonstrate complex procedures. There are benefits shown in research for selected learning objectives, especially for the achievement of procedural learning and student engagement, but long-term effects have not been researched enough.

4.10 AI-Powered Assessment

AI is becoming more useful in the assessment process, for example, by providing automated scoring of constructed responses, plagiarism and cheating detection, creation of assessment items, and analysis of assessment data (Yan et al., 2023). There is potential for automated essay scoring with natural language processing and machine learning to provide feedback on a large scale at speed, but there are concerns about reductionism and bias in complex writing. Plagiarism and contract cheating detection using AI is becoming more effective but has not achieved a level of perfection, especially in the age of generative AI and its ability to create sophisticated text.

Table 1: Major AI Technologies and Their Educational Applications

AI Technology	Primary Educational Applications	Evidence Base	Key Limitations
Machine Learning (Supervised)	Predictive analytics, student risk identification, automated grading	Moderate - 10+ studies showing predictive accuracy	Requires substantial training data, vulnerable to bias in training sets
Deep Learning Neural Networks	Content recommendation, image/video analysis, emotion recognition	Emerging - 10+ studies, mixed results	"Black box" nature limits explainability, high computational requirements
Large Language Models	Content generation, tutoring, feedback	Rapid expansion - 10+ studies 2023-2024	Hallucination problems, training

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AI Technology	Primary Educational Applications	Evidence Base	Key Limitations
	provision, learning support		data biases, authorship questions
Intelligent Tutoring Systems	Personalized tutoring, adaptive instruction, problem-solving support	Strong - 10+ years research, documented learning gains	Domain-specific systems limited in transferability, high development costs
Learning Analytics	Performance tracking, early warning systems, outcome prediction	Growing - 12+ studies demonstrating utility	Privacy concerns, ethical questions about data use and determinism
Natural Language Processing	Automated assessment, plagiarism detection, intelligent tutoring	Moderate – 5+ studies improving rapidly	Continued errors in understanding context and nuance
Computer Vision	Educational robotics, gesture recognition, classroom engagement monitoring	Emerging - 8+ studies	Privacy concerns with surveillance capabilities
Knowledge Graphs/Semantic Networks	Curriculum mapping, concept relationship identification, learning path optimization	Emerging - 5+ studies	Requires significant expert input for knowledge representation

5. OPPORTUNITIES AND BENEFITS OF AI IN EDUCATION

5.1 Personalized and Adaptive Learning

Enabled personalization at scale is amongst the most promising educational applications of AI (Ayeni et al., 2024). Personalized learning systems customize the difficulty, pacing, examples, modalities, and feedback type of learning to the learning characteristics of the individual learner (prior knowledge, learning preference, pace of learning, motivational profile). Personalization, on the contrary, allows instruction to be adjusted to individual needs in order to benefit average learners and disadvantage no one rather than everyone being subjected to the same instruction.Instead of giving everyone the same, personalization means giving instruction that is calibrated to individual needs in order to benefit average learners, and not disadvantage anyone. There is evidence that personalisation can positively influence learning outcomes and engagement, but this can vary greatly depending on the sophistication of the personalisation being used (Suntharalingam, 2024).

The process of personalization is carried out via several mechanisms. Optimize cognitive load by presenting easier content first then more challenging content. Content recommendation suggests resources that are suitable for the learner's needs and interests. Dynamic difficulty adjustment ensures challenge is at the right level for the learner, and creates flowing states that drive engagement (Seo et al., 2021). Personalized feedback is directed specifically towards one's misconceptions, instead of general feedback. Adaptive pacing allows learners to move at a rate that is best for them and helps to minimize boredom and frustration.

But there are some important considerations with personalization. First, the goals of optimization are of critical importance. But systems that focus solely on test score gains could limit learning to items on the test. Second, personalization can amplify preferences and biases

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instead of providing access to a variety of viewpoints, and can lead to echo chambers (Avraamidou, 2024). Thirdly, the presence of comprehensive learner data is essential for meaningful personalisation, which can create privacy concerns. Lastly, to ensure that the personalization works, pedagogical soundness is essential, which is the thoughtful design that is based on learning science principles.

5.2 Enhanced Student Engagement and Motivation

AI educational systems can boost student engagement in several ways, as discussed below (Suntharalingam, 2024). The immediate and personalized feedback allows to receive information about performance and progress at the right time (Fernández-Herrero, 2024). Ensuring a level of difficulty that is neither too easy nor too hard (Tang, 2024). When it comes to learning experiences, interactive interfaces, game elements and personalization are more engaging than traditional textbooks and lectures (Ayeni et al., 2024). AI systems can offer more inclusive learning experiences for certain groups of students, especially those who may feel disconnected from mainstream education.

But it's important to differentiate engagement from learning. Limited learning gains were observed in some very interesting systems (Zawacki-Richter et al., 2019). Motivation for engagement based on game-like features or novelty might not be effective at securing learning. Evaluating the accessibility of AI educational systems is critical and the research separating engagement that fosters deep learning from shallow engagement is valuable.

5.3 Improved Learning Outcomes and Academic Achievement

There is evidence of learning gain achieved by AI educational interventions, as reported in meta-analyses and systematic reviews, especially when they are applied with appropriate implementation (Wang et al., 2024). The effect sizes of intelligent tutoring systems are similar to those of human tutoring (Fernández-Herrero, 2024). Adaptive learning platforms show learning improvements in multiple contexts (Gligorea et al., 2023). Achievement gains achieved through personalized feedback via an AI system (Suntharalingam, 2024). The effect depends on systems, however, considerably, depending on the context some systems show significant gains, others show only minimal benefits. Outcomes are significantly moderated by implementation fidelity and pedagogical quality, as well as by alignment to learning goals.

5.4 Accessibility and Inclusive Education

AI is capable of unlocking significant potential for enhancing educational access and inclusion (Suntharalingam, 2024). Intelligent Tutoring Systems can offer instruction to students with varying disabilities, learning needs and cognitive abilities (Adel, 2024a). AI assistance with text-to-speech or speech-to-text, automated captioning, and gesture recognition can cater for sensory impairments and disabilities (Tang, 2024). Students with learning disabilities and developmental delays benefit from adaptive learning systems which have varying learning rates. In low-resource or remote learning environments, AI tutoring systems provide the opportunity for personalized learning that might not otherwise be possible for students.

Significantly, AI-supported accessibility benefits extends beyond students with disabilities to all learners, as features like adjustable difficulty, multiple modalities, personalized pacing, and scaffolded support benefit all students (Ayeni et al., 2024). By embracing this universal design thinking for AI accessibility, there is no stigmatization and making an environment more inclusive.

5.5 Administrative Efficiency and Teacher Time Savings

AI can handle repetitive tasks in the educational administration process, which frees up teachers' time and enables them to dedicate more time to interacting with students (Tang, 2024). Examples of automated grading and feedback provision abound—objective assessments can

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be instantly graded, preliminary feedback can be given for essays, and common errors can be identified and rectified (Yan et al., 2023). AI can effectively plan courses and maximize space efficiency by analysing enrollment trends. Administrative systems can be used to automate data entry, course registration, and communication. AI has the potential to save teachers the time they spend on administrative tasks and allow them to prioritize substantive teaching – relationship building, higher order teaching, creative teaching, etc.

However, concerns persist. Over-automation and outsourcing of marking could lead to a lack of understanding of learning by teachers and a less personalised feedback. Administrative efficiency also can facilitate cost-saving cuts in teaching positions instead of re-allocation to support services for students.

5.6 Teacher Support and Professional Development

AI systems can help enhance teacher professional development and instructional improvement (Kitcharoen et al., 2024). The application of AI can analyze classroom video data to give feedback on instruction (Grosseck et al., 2023). Intelligent curriculum design systems can help teachers create aligned lesson plans, assessments and resources. Real-time classroom analytics can be used to notify teachers about student struggle and thereby prompt immediate intervention (Tang, 2024). Content creation tools can speed up the instructional materials' preparation (Suntharalingam, 2024). AI-assisted support can offer guidance and resources for teachers in low-resource settings who have limited access to professional development opportunities.

Effective professional learning is critical to unlocking these benefits, as it is a specific focus on AI literacy and AI-integrated pedagogy (Nyaaba & Zhai, 2024). However, teachers need pedagogical knowledge to make use of AI in a meaningful way, not just for its own sake, but as a tool to teach (Arvin et al., 2023).

5.7 Learning Analytics and Data-Driven Decision Making

Learning analytics, defined as systematic analysis of educational data to gain a better understanding and optimize learning, can help to improve the evidence-based educational practice (Jing et al., 2023). Student progress dashboards monitor students' learning trends, providing early intervention for struggling students, and support for redesigning courses with high failure rates, or program outcomes that call for curricular changes (Tang, 2024). The teacher is made aware of the methods that are effective for different types of learners and adapts teaching to the data (Ayeni, et al., 2024). These capacities are for the individual teacher's development as well as institution based evidence-based decision making.

But, the quality of analytics is directly correlated to data quality and analytics interpretation. When data is skewed or lacking, so are the analytics and therefore misinformed decisions. The focus on quantitative measures alone could mask significant aspects of learning that are qualitative.

6. CHALLENGES AND RISKS IN AI EDUCATION

6.1 Algorithmic Bias and Discrimination

Algorithmic Bias, characterized as systematic errors in AI system predictions that affect specific groups, is a critical challenge well documented (Nguyen et al., 2022). Bias can come from many sources: the training data may not be representative of the population, reflecting historical discrimination; the design of the algorithm may include the assumptions of the developer; the deployment context may be biased in which systems are used inequitably (Z. Chen, 2023). In educational systems, biased algorithms can reduce course offerings for students from minority groups, predict lower likelihood of college success for students from diverse

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backgrounds who have identical test scores, and deliver substandard automated feedback to students from specific backgrounds (Alzahrani, 2024).

Algorithmic bias in education has been documented (Díaz-Rodríguez et al., 2023). Machine-learning tools that are based on past data that shows discrimination against marginalized communities continue to perpetuate those trends in the future. Automated essay scoring reflects preferences for certain types of writing that disadvantage students from non-dominant discourse communities. Emotion recognition systems using computer vision have been shown to be less effective at recognizing emotions in marginalized groups and people of color (Alzahrani, 2024).

Three important considerations for tackling algorithmic bias are diverse and representative training data, recognition of potential sources of bias in the design of algorithms, external evaluation of algorithm system performance across demographic groups, and the determination of the outcomes of algorithms instead of simply the aggregate performance (Díaz-Rodríguez et al., 2023). Nevertheless, it is impossible to obtain a perfect debiasing: there are trade-offs between various equity objectives.

6.2 Privacy Concerns and Data Security

An AI educational system needs much data about the student, such as past performance, learning behavior patterns, demographics, and even biometric or behavioral indicators (Han & Kumwenda, 2024). Data collection is large-scale and there may be privacy concerns due to the possibility of data breaches (Alzahrani, 2024). The data gathered for educational use may be used in problematic ways such as algorithmic discrimination in career guidance, targeting vulnerable learners in advertising, and predictive profiling outside the educational context.

Educational data is not collected, stored or accessed by students and families in ways that they understand. Students and families do not know how or why data are collected, stored, or accessed. (Han & Kumwenda, 2024). Often there is lack of or confusing consent for data collection, which is hidden inside the terms of service. Sophisticated attackers are often able to overcome institutional data security (Kaissis et al., 2020). There are regulations such as GDPR and COPPA that try to set these standards, but they're not always well-enforced and the technical capabilities are often greater than the regulations.

6.3 Concerns about Academic Integrity and Plagiarism

As generative AI systems gain popularity and become more prevalent in higher education, significant questions have emerged regarding academic integrity: what constitutes original student work when students can use AI tools to write essays, solve problems, or produce content (Sullivan et al., 2023)? Generative AI can easily generate convincing academic papers, functional code, and mathematically sound responses, with the potential to deceive traditional assessment of student work (Perkins, 2023). Academic integrity policies designed before the advent of AI provide little support for situations where the student may rightfully use AI tools and programs, as well as when they may wrongfully delegate learning.

AI-generated content can often lead to false positives and false negatives, which is a challenge for plagiarism detection systems (Sullivan et al., 2023). On the other hand, students who have more advanced strategies might not be caught at all (Perkins, 2023). Some teachers call for a radical restructuring of how students are measured – away from the traditional multiple-choice paper test and towards performance, projects and demonstrations that can't be outsourced to an algorithm. Others try out open AI usage – explicitly allowing students to use generative AI, yet clearly and accurately documenting and evaluating authentic student contribution.

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6.4 Hallucination Problems in Generative AI

A phenomenon that is well documented in the use of LLMs is the "hallucination" of information, information that is completely fabricated and confidently claimed (Sallam, 2023). This is a serious problem in educational settings. The information provided by ChatGPT might be inaccurate because it is presented as authoritative and trustworthy, leading students to believe that it is true and to internalize falsehoods (Sallam, 2023). Generative AI tools can inadvertently embed misinformation when creating teaching content, as can be the case with teachers (Sallam, 2023). The models' habit of making false claims, fabricating history facts or describing nonexistent research, jeopardizes education-based uses that rely on accuracy (Cooper, 2023).

The hallucination phenomenon is due to the fact that language models predict words that are likely to occur next based on statistics, not on real information. They have no access means to find out whether the knowledge is real knowledge or whether it is learned statistical patterns. Hallucination resistance requires technical improvements (retrieval-augmented generation that includes ways to look up information that is not included in the model) and user education on model limitations.

6.5 Digital Divide and Educational Equity

While AI holds promise for increasing access to education, disparities in the availability and access to AI tools could contribute to deepening digital divides (Capraro et al., 2024). In well-funded schools and universities in rich nations and areas, the advanced AI-education systems are introduced and may improve the quality of education. At the same time, schools in lower-income areas are unable to access sufficient funds, and continue to use outdated resources, leading to a growing gap (Han & Kumwenda, 2024). The digital divide takes place at various levels such as limiting Internet bandwidth, lack of devices, and lack of teacher professional development, as well as lack of institutional support, all of which hinder the use of AI where it is most needed.

Further, AI is developed within a specific context and priorities of well-resourced institutions, which may result in the development of systems that do not meet the needs of marginalized groups (Avraamidou, 2024). Most of the educational AI is created in a context of wealth in the North for a North context, and with the requirement of resources in many contexts that are not available, such as reliable electricity and high speed internet, and technical support.

6.6 Teacher Readiness and Professional Development Gaps

The role of the educator is crucial to the realization of the potential of AI in education, as he or she needs to have a solid grasp of the capabilities and limitations of AI, as well as a sound pedagogical understanding of how to integrate AI in a meaningful way, troubleshoot technical issues, and ensure that AI is used ethically (Nyaaba & Zhai, 2024). However, the current teacher preparation is far from meeting this need (Arvin et al., 2023). There is little to no preparation about AI by most educator preparation programs, and teachers are left to use their own resources to learn about AI, which are limited and superficial (Nyaaba & Zhai, 2024). Teachers often feel ill-equipped to utilize generative AI in particular, and lack confidence in how to keep pedagogical integrity when engaging with generative AI (Arvin et al., 2023).

In addition, professional development training on AI tends to focus on technical aspects rather than pedagogical approaches, leading to uncertainty among teachers about authentic AI integration. Teachers tell us that we need guidance when redesigning assessments, using AI ethically, and in ways that foster the critical human aspects of teaching (Nyaaba & Zhai, 2024). If there is not significant investment in the intentional, continuous, pedagogically-informed

professional development of educators, then the conversation of using AI might become superficial tool use and not result in any meaningful educational changes.

6.7 Infrastructural Limitations and Cost Barriers

Implementing advanced AI educational systems is a significant investment in infrastructure, including high-speed internet, computing power to run models, technical support for system maintenance, and software updates (Han & Kumwenda, 2024). These costs will add to the challenges, especially for schools in low-income communities and developing countries whose budgets are already low (Song et al., 2021). Some mitigation is available from open-source and freely available AI tools, but it's extremely costly for many institutions to access premium educational AI systems.

The infrastructural needs are not only technological, but also human, such as administrators to supervise the implementation of the ICT, data specialists to manage the education data, technical support people who need higher expertise and salaries that are not within the budget of many institutions (Adel, 2024a).

6.8 Lack of Clear Governance, Policy, and Ethical Frameworks

AI adoption in education is outpacing the development of AI policies for education (Nguyen et al., 2022). Only a handful of educational institutions have comprehensive policies about AI usage, protection of data, transparency regarding algorithms, safeguards for students, and ethics in deployment (Chan, 2023). There is a lack of technical knowledge among many policymakers to create AI-informed policies (Díaz-Rodríguez et al., 2023). The international policy frameworks on AI in education are still in their early stages and, so far, there are not enough policies to inform and support institutional decisions from UNESCO and other institutions.

There are still some key policy questions that have yet to be answered: Whose responsibility is it if AI systems inflict educational harm? What are the implications for protecting educational data when intensity of collection? What are the transparency requirements? Who needs to be involved in decisions about implementation of AI? If there are no clear frameworks, implementation takes place in an ad hoc manner, with inconsistent practices, and student/family protections are inadequate.

7. EMERGING TRENDS IN AI AND EDUCATION

7.1 Generative AI and Large Language Models in Education

One of the most noticeable developments is the use and exploration of generative AI, especially large language models, in the educational setting (Mahrishi et al., 2024). In their research, teachers and students are learning about ChatGPT and other systems to help them write, create content, prepare for exams, conduct research, and so much more.Teachers and students are learning about ChatGPT and other systems to assist them in writing, creating content, test preparation, research, and so much more (Rasul et al., 2023). Schools are creating policies which seek to meet the need for the legitimate use of technology while minimizing opportunities for the violation of academic integrity (Sullivan et al., 2023). The incorporation of generative AI into learning platforms, tutoring systems and assessment tools by educational technology firms (ETF) (Bewersdorff et al., 2024).

The research surrounding the use of generative AI in education has grown exponentially, with almost 100 empirical studies published in the last two years (2023-2024) alone (Mahrishi et al., 2024). This research notes the advantages of development and use of personalized feedback on writing, accessible tutoring support and adaptive learning support, but also concerns about the development and use of contract cheating, and the reduction of student authentic engagement and plagiarism. (Lo, 2023) The integration of generative AI in education is a subject of significant debate, with teachers torn between the fear of potential threats that need

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to be controlled and the hope of new opportunities that must be embraced (Rudolph et al., 2023).

7.2 AI-Powered Curriculum Design and Content Generation

AI systems that support the development of curriculum and instructional content are an emerging potential application (+, 2024). These systems can support mapping curriculum to standards, finding gaps in alignment, recommending systems of progression, producing practice problems, and producing a variety of different instructional materials (-, 2024). AI can be used to create lesson plans, assessments, and learning objects in bulk, which could help improve access to quality instructional materials, especially in settings with limited resources (Baidoo-Anu & Ansah, 2023).

This is, however, a cause of concern with regard to curriculum homogenization and a number of loss of teacher curricular agency (-, 2024). When curriculum is created by AI and applied consistently, there is a loss of opportunities for culturally responsive and locally contextualized learning. Also, the quality of the AI-generated curriculum needs to be validated; not everything the AI produces is necessarily high-quality pedagogy.

7.3 AI Co-Pilots and Augmented Pedagogy

While the common misconception among many is that AI can replace human teachers, there is a notable shift in the industry towards viewing AI as a supplementary tool or “co-pilot” for human educators, thereby increasing their capacity (Eager & Brunton, 2023). This view highlights the ability of AI to manage repetitive tasks—such as grading, scheduling, and first contact with frequently asked questions—and frees up time for teachers to concentrate on tasks that cannot be replicated—such as depthful relationships, complex problem solving facilitation, ethical reasoning, mentoring and inspiring others (Thorne, 2024). Co-pilot relationships need a good design of the interface, an appropriate division of tasks and transparency of the relationship.

7.4 Virtual Teachers and Embodied Learning Agents

The sophisticated virtual teachers and embodied learning agents (EBLAs) (S. Chen et al., 2023) are an emerging current trend in the field. These systems offer tutoring, mentoring, and companionship in learning, especially useful for students who are socially anxious, second language learners, and in resource-limited environments (S. Chen et al., 2023). Multimodal system for text, speech, video and gesture recognition, providing more natural interaction.

7.5 Immersive Learning with AI and Extended Reality

The use of artificial intelligence (AI) alongside augmented reality (AR), virtual reality (VR), and mixed reality (MR) helps to create engaging learning experiences enhanced by AI assistance and adaptive support (Allam et al., 2022). AI systems can customize immersive experiences, tailor the difficulty level of scenarios to fit the learner's performance, offer intelligent guidance, and evaluate learning in immersive environments (Adel, 2024a). They can be used in virtual labs for science, historical simulations, professional practice and rehabilitation training, among others.

7.6 Predictive Analytics for Student Success

Predictive analytics are increasingly being used in educational institutions to identify students at risk, predict the likelihood of degree completion and predict the likelihood of success in their future careers (Jing et al., 2023). These systems involve analyzing large-scale student data, such as academic performance, course selection, behavior, and demographics, to make predictions for targeted interventions (Tang, 2024). The use of potentially useful tools in identifying pupils in need of assistance is fraught with concerns over algorithmic determinism, self-fulfilling prophecies and the ethical issues of profiling.

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7.7 AI for Educational Leadership and Administration

AI applications are now becoming more widespread in the field of education, where it helps with educational leadership and institutional management, for instance (Saaida, 2023). Systems can use institutional information to analyze, visualize trends, predict resource needs, optimize scheduling, facilitate strategic planning and identify opportunities for improvement. AI can also be a valuable tool for accreditation and quality control, ensuring that compliance and outcomes are analyzed.

8. GLOBAL PERSPECTIVES ON AI ADOPTION IN EDUCATION

There is a wide range of global contexts for the adoption of AI in education, ranging from areas with high economic and technological resources to others with a lower capacity, as well as from policy contexts to priorities.

8.1 North American Context

The U.S. and North America as a whole are pioneers in global AI educational research and development (Mahrishi et al., 2024). Many AIED studies are done in American universities, many AI systems are created by American technology companies (OpenAI, Google, Microsoft), and American schools are increasingly using AI platforms.There is a significant amount of AIED research done in American universities, leading technology companies (OpenAI, Google, Microsoft) develop most of the AI systems, and American schools are applying AI platforms more and more. Adoption rates, however, are far from uniform; richer school districts in rich areas have more sophisticated systems while poorer districts in urban and rural areas are far behind (Han & Kumwenda, 2024). Policy efforts continue to be decentralized, with varied policies on issues of data privacy, algorithmic transparency, and protections for students in state and institutional responses.

8.2 European Perspective

The European Union has more extensive AI governance frameworks, such as demands for explainability, fairness and human oversight, than many regions, including (Díaz-Rodríguez et al., 2023). European policy focuses on human-centric AI and strong safeguards for citizens, such as GDPR and new AI regulations (Chan, 2023). The ethics in the application of AI and equity are highlighted in educational research across Europe (Nguyen et al., 2022). There is however a significant spread across Europe, with Nordic countries, UK and Western European countries being ahead of the Eastern European countries.

8.3 China's Strategic Approach

The Chinese government has designated AI as a key priority and is investing significant resources in AI research, development, and application in various fields, such as the education sector (Zawacki-Richter et al., 2019). The educational AI systems are being developed and deployed by Chinese technology companies (Alibaba, Tencent, Baidu). AI is actively being encouraged by government policy in school, so much so that AI literacy is seen as essential for competition in the future. There are concerns, however, about surveillance and centralized control in chinese approaches rather than in western approaches where the emphasis is on systems being integrated into the state.

8.4 Developing Countries and the Global South

The use of AI in education is still limited in most of the developing countries and Global South countries (Alami et al., 2020). Financial and investment constraints, poor internet connectivity, lack of technical skills are limiting factors that hinder adoption (Han & Kumwenda, 2024). There are, however, countries that also see the possibility of AI to solve the educational problem of preparing a large number of students to go to school, to reach remote areas, to fill the lack of teachers (Song et al., 2021). Mobile access and low bandwidth based on AI have

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shown promise in the resource-constrained contexts (Song et al., 2021). Additionally, open-source and freely available AI tools provide opportunities for educational access without prohibitive costs.

8.5 Critical Issue: Geopolitical and Cultural Context

An emerging important recognition is that the implementation of AI in education is not culturally neutral and/or geopolitically de-contextualised (Avraamidou, 2024). Al systems created in one context, such as North America or China, might have values, assumptions, and biases that are not relevant to others. Artificial Intelligence-generated curriculum could align with dominant knowledge and epistemologies and exclude alternative ones. Ethics guidelines for AI created in the developed and Western world might not reflect the values of diverse cultural contexts.

Progress on a global level must include: (1) AI development including geographic, cultural, and economic diversity; (2) cautious localization of systems to specific contexts, instead of uniform global deployment; (3) awareness of the intersection of educational AI and issues of cultural preservation, decolonization and knowledge sovereignty; (4) capacity building in developing countries for engagement in AI development, rather than only consumption.

9 Artificial Intelligence in Developing Countries: Infrastructure, Teacher Readiness, Digital Literacy, Funding, and Policy Readiness

The introduction of artificial intelligence (AI) in education is a game-changer for developing countries that continue to experience educational disparities and need to improve learning outcomes on a large scale. Yet the actualization of this potential is still extremely difficult. Developed nations are progressing rapidly toward incorporating AI into their businesses and public spaces, emphasizing the necessity of strong infrastructure, substantial financial backing, and the creation of skilled professionals to handle these innovations.Developed countries are making strides toward integrating AI into public spaces and business, underscoring the critical need for robust infrastructure, significant investments, and trained workforce to keep pace with these innovations. This extensive literature review covers five interrelated aspects of the implementation of AI in developing countries: infrastructure capacity, teacher readiness and competencies, digital literacy levels, funding schemes, and policy frameworks. By conducting the in-depth literature review, we uncover the obstacles and facilitators surrounding the use of AI in education, providing evidence-based strategies for equitable and sustainable AI integration.

9.1 Infrastructure and Technological Capacity

9.1.1 Current State and Critical Deficits

The most obvious obstacle to the use of AI in educational systems in developing countries is infrastructure. A number of studies have been conducted on the implementation of digital technology in the education sector, in which the lack of infrastructure and insufficient internet connection were found as major barriers to the successful deployment of digital technology in education. This is a pattern that is repeated across the globe; a study of the transformation of STEM education in Africa by Barakabitze et al., (2019) shows that some countries, such as the nations of Africa have made advances towards the transformation of STEM through such innovations as living labs and innovation labs, however, most of the sub-Saharan nations have not yet developed the technological infrastructure, the basic foundations, required for meaningful implementation of AI. Availability of devices is not the only challenge as it includes a strong infrastructure for electricity provision and internet connectivity, along with comprehensive data management systems.

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(Han & Kumwenda, 2024) Researchers who studied the topic of inequity in online learning in medical education highlighted that digital inequity is an inherent part of digital infrastructure that can be traced back to historical socioeconomic inequities between the global North and South. Developing countries are known as the "triple infrastructure challenge" countries: they have low availability of reliable electricity and Internet in both rural areas and under-served urban areas; they have low availability of computing hardware and software; and they have weak Data Storage and Cybersecurity infrastructure that is not compatible with large-scale AI systems.

9.1.2 Connectivity and Digital Access Inequities

There is still a lack of digital connectivity in developing regions and even within these regions, the geographical and sectoral coverage is uneven. These infrastructure gaps were starkly exposed during the COVID-19 pandemic. Studies of the impact of educational interruption during COVID-19 from several countries found that the exacerbation of digital divide led to unequal access to online education, highlighting the systemic vulnerabilities in developing country infrastructure during the COVID-19 emergency remote teaching.

9.1.3 Infrastructure Solutions and Recommendations

Solving infrastructure problems demands multi-phased and integrated solutions. (Brunetti et al., 2020) A multi-stakeholder study of digital transformation strategies has revealed that infrastructure development is one of the key pillars that needs to be coordinated between companies, governments, and educational institutions, highlighting the importance of both the information technology infrastructure and the knowledge ecosystem. The research highlights the importance of moving beyond the technological solution and highlights the importance of a systemic perspective on infrastructure, as well as capacity building and partnership ecosystems. Moreover, as reported in (Alenezi, 2023), the use of AI in higher education demands a thorough grasp of the technology's role in contemporary education environments, which goes beyond simply purchasing a product.

9.2. Teacher Readiness and Competencies

9.2.1 Competency Frameworks and Assessment Gaps

The readiness of teachers to use AI is likely the most important factor for successful implementation, and there remains a great need for more teachers who are prepared to use AI. A detailed critical analysis of the AI competences of teachers in the literature has shown that, despite the increased attention in the literature on the need for teachers to acquire digital AI competences, the existing AI competence frameworks are not well defined (Mikeladze et al., 2024). The review found five different kinds of AI competence frameworks, both empirically based and theoretically based, providing more detailed descriptions of competency on the one hand and broader overviews on the other, but none covering both developing country contexts and a full set of competencies.

9.2.2 Teacher Training and Development Challenges

There is a big disparity between teachers and the need for AI to be ready. The study of teacher educators in Ghana found that there was a wide range of familiarity with Generative AI with some teacher educators having no prior exposure to the tools. Notably, the participants highlighted multiple infrastructure issues, such as the cost of premium AI tools, the lack of training on AI prompts, and ethical clarity issues, as challenges to implementation. The study highlighted the need for institutional support to teacher educators and the inclusion of AI literacy in their continuous learning. The research on improving teachers' AI competencies through extensive professional development training emphasized that although teachers' lack of basic knowledge was a major obstacle to AI education, intensive PD workshops are helpful

to develop competence (knowledge, skills, and attitudes) in the use of AI (Kitcharoen et al., 2024).

A study on AI literacy in teacher education revealed globally that AI has become a topic on the education agenda, while it is virtually not mentioned in teacher education contexts. When teachers have practical experience, they are more likely to accept digital resources than apply AI to the learning and teaching process. There are critical gaps in the theoretical understanding or the epistemic knowledge of teachers, in their practical-productive knowledge or their capacity to apply knowledge, and in their professional judgment or phronesis, with ethics being mostly seen as technical knowledge, that is, as theoretical knowledge.

9.2.3 Contextual Factors Affecting Teacher Adoption

The study found three main themes in the teachers' experiences with AI tools for education: perceptions of the effectiveness of AI, difficulties in integrating AI into the classroom, and teacher development requirements. Although educators saw pedagogical advantages, such as personalization and better engagement, they also faced a number of challenges such as technical difficulties, lack of support and teacher preparedness. Most importantly, the study highlighted the need to enhance digital literacy among teachers, to make the use of AI resources more equitable, and to create more detailed ethical guidelines to fully realize its potential for transformation.

9.3. Digital Literacy and Skills Development

9.3.1 Digital Literacy Disparities and Inequities

The uneven distribution of digital literacy (knowledge, skills, attitudes, and values for effective technology use) is a foundation block that hinders AI adoption across developing countries. According to a literature review on digital literacy (Reddy et al., 2020), people need to develop different competencies and skills to cope with the technological era; however, there are still gaps in the development of ICT and growth of the internet. Digital literacy is not just about computer literacy but about thinking about technology and how technology can be used ethically, using the ability to adapt to learning.

9.3.2 AI-Specific Literacy Requirements

Four salient components were identified in the designing and validating research of an AI literacy questionnaire: affective (intrinsic motivation, self-efficacy), behavioral (commitment, collaboration), cognitive (knowing, understanding, applying, evaluating, creating), and ethical learning. A number of important patterns were found in the measurements conducted among students, but of particular importance, little information is found on the development of these dimensions in contexts with fewer resources. While competency frameworks should be at a local level and flexible to meet local needs and circumstances, empirical evidence about what students have learned from AI experiences is still limited, and issues related to unintended negative outcomes of careless, under-researched use of AI have not been explored.

9.3.3 Building Digital Literacy in Developing Contexts

Study of mobile-assisted personalized learning suggests that digital literacy development in developing countries does not have to rely on advanced technologies and infrastructure, but rather on the fact that mobile devices are ubiquitous, that connectivity is flexible and that concepts of personalized learning can serve as a vehicle to overcome digital divides. This is a strategy that takes into account the conditions in developing countries, where mobile devices are the main means of technology access. The focus on AI literacy, prompt engineering, and critical thinking skills in contemporary education pointed out that the use of AI is a departure from traditional education and needs to be trained well for teachers and curriculum adapted.

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9.4. Funding and Financial Sustainability

9.4.1 Funding Gaps and Resource Constraints

Funding shortfalls are essential constraints to implementing AI in education systems in developing countries. The study found that while AI offers a promising solution to challenges and helps mitigate gaps in education systems, its adoption would require significant investment in infrastructure, teacher training, and ethical guidelines, which are not resources that are readily available in sub-Saharan Africa. (Chisom et al., 2024) Ongoing support for professional development, system maintenance, and continuous improvement are necessary for sustainability, as well as initial capital investment.

9.4.2 Funding Allocation Priorities

In the case of developing countries where the budget of AI education is relatively small, it is a challenging allocation problem. (Brunetti et al., 2020) Multi-stakeholder research on digital transformation strategies concluded that key funding needs are culture and skills development, infrastructure and technology, and ecosystem development (partnerships and long-term visions). A concerted effort to reconfigure business models in companies, to create a conducive environment for cooperation between institutions, and to offer thorough training to various groups was stressed. However, in resource-poor environments, this is typically unfeasible due to limited budgets. The thorough review of big data and AI in education by (Luan et al., 2020) found that government investment needs to focus on lifelong learning, teacher training and safeguarding personal data, but there is a lack of institutional capacity to support these integrated approaches in many developing countries.

9.4.3 Alternative Funding Models

In developing countries collaboration with other countries and public and private partnerships are identified as important funding sources. Studies on capacity building in LMC countries found that local government support and international NGO collaboration were both facilitators to capacity building, and that there was a need to facilitate collaborations with developed countries to support funding, training, education and sharing of resources. Yet, (Avraamidou, 2024) a critical analysis of AI colonization of science education warned of the dangers of inequities in AI science funding, which would benefit wealthier nations and corporations at the expense of poor, marginal communities in ways similar to that of history's colonial powers. This is a concern that highlights the need for locally managed and ethically-based funding.

9.5. Policy Frameworks and Governance Readiness

9.5.1 Global Policy Landscape and Developing Country Contexts

Global policy frameworks related to AI in education are still at a fledgling stage, and are even less developed in developing nations. A detailed overview of AI regulation and governance globally highlighted the challenge of developing robust regulatory frameworks to effectively govern rapid advancements, underscoring the varying regulatory approaches in different regions. (Walter, 2024) The study identified complexities and challenges in creating a coherent policy, and looked at the relationship between the speed of innovation and the lag time between the ethical standards. The UNESCO Beijing Consensus on AI and Education, created during the 2019 international conference attended by 50 government ministers and 500 international representatives, set down key principles which can be applied to developing countries: AI development should be human-controlled, people-centred, monitored throughout value chains during deployment and protected teachers' working conditions.

9.5.2 Ethical, Regulatory, and Rights-Based Frameworks

Trustworthy AI systems have three pillars that need to be present: lawfulness, ethical grounding and robustness (technical and social). (Díaz-Rodríguez et al., 2023) The framework consists of

seven technical requirements that must be adhered to throughout the lifecycle of AI systems: human agency oversight, robustness, privacy, transparency, fairness, societal wellbeing, accountability. Adopting such frameworks for developing countries has substantial institutional difficulties. Using systematic analysis of current policies of international organisations, Nguyen et al. (2022) identified ethical risks linked to the use of personal data and learner's autonomy as well as the debate on main ethical principles supporting AIED. The research put forward frameworks which were meant to inform and guide stakeholders in development and deployment.

9.5.3 Context-Specific Policy Development for Developing Countries

Studies on the creation of comprehensive AI policy education suggested a multi-layered approach in terms of both teaching and learning, governance and policy formation, and operationalization. This is a structured way for developing countries to develop policy. [(Capraro et al., 2024) Study on the socio-economic impacts of generative AI noted that while policy making is a key element in enhancing the positive effects of generative AI and mitigating its negative effects, existing policies are inadequate to tackle the challenges identified. The proposed research identified specific policy recommendations for shared prosperity, including immediate need for cooperative strategies to understand the complex socioeconomic impacts.

9.6. Synthesis and Integrated Framework for AI Implementation in Developing Countries

9.6.1 Interconnected Dimensions and Systemic Challenges

The five dimensions explored – infrastructure, teacher readiness, digital literacy, funding, and policy – are not separate issues but rather are interrelated. In an examination of "shadows" of AI in Education, (Alzahrani, 2024), there were correlations between various concerns related to AI which indicated that the concerns are intertwined rather than distinct. For instance, AI transparency can be used to help both teachers and students develop, while also simultaneously improving student outcomes. This oneness of everything demands systematic rather than fragmented solutions.

9.6.2 Equity and Inclusion Imperatives

A comprehensive study by Capraro et al. (2024) of the implications of generative AI on socioeconomic inequalities revealed that while generative AI can be used for personalized learning, it may also contribute to the growing digital divide. AI in education is characterized by personalized learning and has the potential to deepen the digital divide by providing unequal benefits. This risk is especially high in developing nations, where the conditions of inequality already restrict access to learning. The study on the integration of AI in education by (Eden et al., 2024) highlighted that AI tools have immense transformative potential in education but robust oversight is crucial to ensure their implementation is both accessible and addresses digital divide and data privacy concerns. To create fair results, attention must be paid to the marginalized, the rural and the economically disadvantaged.

9.6.3 Recommended Implementation Roadmap

The in-depth analysis of major obstacles to AI use shows that the most critical are teacher training and readiness, funding and resources, and equity/access issues. There is also a significant need for attention to infrastructure deficit, digital literacy gaps, and policy frameworks. These multi-year challenges need to be dealt with in an integrated way.

The factors that make a project successful, such as strong government support, international cooperation, public-private partnerships and context adaptation, are significant. Implementation should require participation of everyone (governments, educational institutions, teachers), and the allocation of the budget should be optimal, with a particular focus on spending on teacher development and infrastructure upgrades.

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9.6.4 Critical Success Factors for Developing Countries

AI applications in personalized learning and education highlighted key takeaways regarding the importance of considering a wide range of applications from adaptive learning to intelligent tutoring systems, as well as ethical concerns such as privacy, algorithmic bias, and digital divide issues. The study highlighted the importance of partnerships between teachers, policymakers, and technologists to set standards for equity-based resource distribution. A study on the potential of AI in Africa's education system (Chisom et al., 2024) found that effective and sustainable deployment of AI in Africa's education system will likely require a concerted effort between the government, schools, developers in the private sector, and communities. Case studies demonstrated successful pilot projects, but emphasized the need for policy recommendations to lead responsible integration that is sustainable and culturally-appropriate. Although the potential of AI to revolutionize education in developing nations is undeniable, it demands tackling complex interrelated hurdles in infrastructure, human capacity, digital skills, financial constraints, and governance. The evidence reviewed across this review shows that no single intervention will do – a systemic approach which simultaneously enhances infrastructure, supports teacher capabilities, fosters digital literacy, provides ongoing funding and establishes a broad ethical policy framework is key.

Its use in developing countries should not be applied as is from high-income country contexts, but should be led by developing countries to co-created solutions that are both locally focussed and locally grounded in local assets and values. International cooperation is vital for support, and local leadership for cultural appropriateness and sustainability. Regardless of the level of technology, meaningful learning is still teacher-driven, and investment in teachers should be the top priority. Ethics should be addressed before implementation, not after, and should be designed so that AI development is for human flourishing and equity, not perpetuating or exacerbating the problems already confronting humanity.

Political commitment, consistent financial investment, sincere international cooperation, and a relentless focus on equity are the keys to the path forward. AI in developing countries has the potential to address educational gaps, promote quality education for all, and aid in sustainable development, when harnessed responsibly and ethically. The time to act is now, and should be based on evidence, ethical principles, and focused on learners and communities who will shape the future of educational transformation or technological colonization through the use of AI.

10 AI AND THE FUTURE EDUCATION SYSTEM: An Analytical Framework

10.1 Future Classrooms

The use of AI in classrooms will revolutionize teaching and learning methods. Multimodal Large Language Models (MLLMs) with capacities to interpret text, audio, and visual inputs usher in new chapters of enriched, personalized, and interactive learning environments. Future classrooms will be a mix of physical and virtual spaces, with AI a tool to assist, not supplant, the human teacher.

10.2 Future Teachers

The role of educators is shifting to higher order thinking, values, and learning processes, not content. There will be specific institutional roles for Data Privacy Coordinators and Equity Specialists that teachers will need. Professional development should focus on AI literacy, the skills to use prompt engineering, and the development of critical thinking abilities to support students' interactions with AI.

10.3 Future Learners

(Ayeni et al., 2024) Future learners will experience AI-driven personalized education tailored to their unique preferences, pace, and learning styles. These learners will acquire the skills of

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problem solving, emotional engagement, scientific citizenship and authentic learning in human-centric AI-enhanced experiences.

10.4 Future Assessment

AI-driven evaluation will move from fixed assessments to personalized, on-the-fly feedback and interventions, enhancing learning outcomes. Multimodal assessment will include traditional assessment measures as well as behavioral and engagement measures, with the use of intelligent tutoring systems.

10.5 Future Curriculum

With the power of AI, curriculum development will become more intelligent, allowing for the creation of more intelligent and multimedia-rich content with interactive features and personalised learning paths.AI-enabled curriculum development will empower intelligent content creation, incorporating multimedia elements, interactive features, and custom learning trajectories. Emphasis will be placed on lifelong learning and transferable skills such as communication, critical thinking, creativity, leadership and emotional intelligence in addition to the content of the subjects.

10.6 Future Governance

There are three dimensions of governance: Pedagogical (improve learning outcomes), Governance (privacy, security, accountability), and Operational (infrastructure, training). (Chan, 2023) Stakeholders such as students, teachers, technology developers, policy makers, and institutional decision makers should be guided by ethical principles (Nguyen et al., 2022).

10.7 Future Universities

Smart universities will transform learning and administration processes by leveraging quantum technologies and delivering personalized learning paths, better access for all learners, and economic efficiency by smartly implementing the technologies while taking into account quality issues, job displacement risks, and algorithmic bias.

10.8 Future AI-Driven Education Ecosystem: A Conceptual Framework

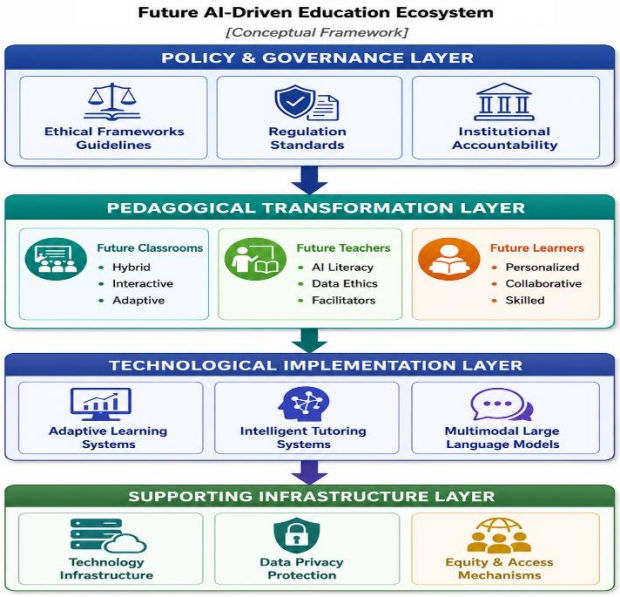

Figure 1. Future AI-Driven Education Ecosystem

10.3 PROPOSED CONCEPTUAL MODEL

Integrated Framework for AI-Enabled Educational Transformation

The proposed model is based upon four components that are cross-referenced:

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AI Technologies Component (Ayeni et al., 2024): This is the base layer of AI technologies, including adaptive content delivery, real-time feedback, and intelligent tutoring systems. These should be performed transparently, with interpretability and ethical boundaries to avoid propagating biases.

Educational Processes Component (Eden et al. 2024): Educational processes involve the use of AI tools in curriculum design, tailoring teaching methods to individual students, and simplifying administrative tasks. Yet, all these processes must retain a human connection and educators' agency at their heart, with AI playing an augmentative, not a replacive role.

3. Educational Outcomes Component (-, 2024) Key outcomes are a dramatic increase in academic achievement, engagement and motivation, increased real-time feedback and interventions, and the development of critical thinking and problem-solving skills.

Societal Impact Component (Capraro et al., 2024): The potential benefits of democratizing education and increasing access to education, but also the risks of digital polarization and further social inequalities, if not managed properly with inclusive policies and equitable distribution of resources.

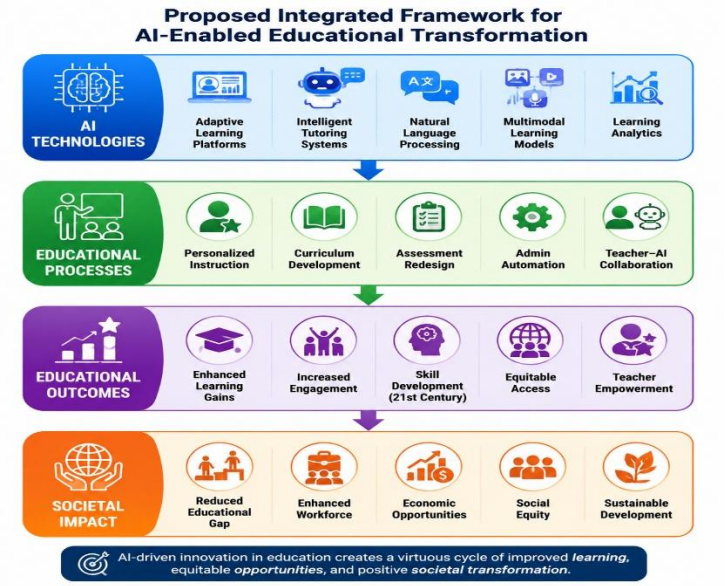

Figure 2. Proposed Integrated Framework for AI-Enabled Educational Transformation

11 ETHICAL GUARDRAILS & GOVERNANCE

- Privacy & Data Protection
- Algorithmic Fairness & Transparency
- Accessibility & Inclusion
- Human Agency & Autonomy
- Environmental Sustainability

12 RESEARCH GAPS

Theoretical Gaps

Research finds that the use is more dominant in Adaptive Systems in Personalisation in the field of education, while in the theoretical aspect there is a gap in how to balance technological innovations and human-centered pedagogy. Whilst some of the studies reviewed are atheoretical (even though they have implications for learning, knowledge production and socio-emotional development), most of them are lacking in criticality and theoretical foundation.

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Methodological Gaps

Based on the literature gaps, further ethical, methodological, and contextual aspects need to be addressed in future AIEd research, as well as interdisciplinary approaches to the application of AI in EI. The evaluation of different educational settings and tools for assessing the effectiveness of AI interventions is limited.

Geographic Gaps

There are significant gaps in critical research, especially in Low- and Middle-Income Countries (LMICs), and a disproportionate focus on high-income countries, such as North America and Europe. (Capraro et al., 2024) Development of digital learning solutions that are relevant to the local context is hindered by the absence of voices from the Global South.

Policy Gaps

The lack of human connection, privacy and security of data, algorithmic bias, lack of transparency, and the impact of AI-generated content are all concerns that have been substantiated by research (Alzahrani, 2024). However, policy frameworks do not adequately address identified problems. As guidelines for trusted AIED were announced (Nguyen et al., 2022), discussion on the principles of the implementation of AI worldwide remains.

Equity Gaps

To guarantee the equitable sharing of AI-powered resources, issues related to privacy, algorithmic biases, and digital divide disparities must be addressed. The use of algorithms in consequential decision making raises concerns about transparency and accountability for widespread implementation (Eden et al., 2024).

Table 2. Summary of Research Gaps and Future Research Agenda

Gap Category	Current State	Future Research Agenda	Priority
Theoretical	Limited grounding in pedagogy	Integrate educational theory with AI design	High
Methodological	Lacks rigor and validation	Establish robust assessment frameworks	High
Geographic	LMIC underrepresented	Conduct research in diverse contexts	Critical
Policy	Fragmented guidelines	Develop comprehensive regulatory frameworks	High
Equity	Access disparities	Study inclusion mechanisms	Critical
Implementation	Limited real-world evidence	Scale and evaluate interventions	Medium
Teacher Readiness	Insufficient training	Design robust PD programs	High
Ethical	Sparse guidelines	Establish ethics review processes	Critical
Sustainability	Unknown long-term effects	Longitudinal impact studies	Medium

13 PRACTICAL IMPLICATIONS

13.1 For Policymakers

(Capraro et al., 2024) Policymakers need to achieve the full potential of AI to address inequalities and ensure that its impacts are avoided through clear policies that promote shared prosperity. Policy frameworks should address pedagogical, governance and operational dimensions, ensuring the understanding of stakeholders' roles and actions to take. (Krotz &

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Schelhowe, 2020) Legal provisions should ensure non-discriminatory and equitable data re-use, adapted to the responsible learning principles.

13.2 For Educational Leaders

It is important for leaders to motivate educators, policymakers and stakeholders to work together and innovate on creating smart education solutions that are effective. To ensure that technology is relevant, accessible, and effective, strategic planning and collaboration are key. (Aithal et al., 2024) Schools require DPCs and Equity Specialists.

13.3 For Teachers

Teachers need in-depth professional development that focuses on digital literacy, ethical issues, and policies that support them. Teachers need to become AI-literate, become proficient in prompt engineering and cultivate a critical thinking approach in order to work effectively with AI and students. The use of AIoT professional development training has the potential to enhance the educators' knowledge, skills, and attitudes.

13.4 For Curriculum Developers

The curriculum designers need to embrace the flexible hybrid models and rethink about their strategies that involve using the AI for literacy as an essential component. (Grosseck et al., 2023) Pedagogical, psychological, and sociological concepts need to be integrated into frameworks to grasp the holistic role of AI in learning and remain focused on human development.

13.5 For Researchers

Beyond proof-of-concept demonstrations, researchers need to take the step to broadened adoption, grounded in theory and empirical testing. (Luan et al., 2020) (Holmes et al., 2021) A well-designed framework engaging multidisciplinary approaches and robust guidelines seems vital for the AIED context.

13.6 For Technology Developers

It is crucial for the developer and educators to work together with policymakers to ensure equitable distribution of resources enhanced by AI (Ayeni et al., 2024). During designing and deployment phase, attention needs to be paid to data quality, data volume, data privacy matters, data security, bias, fairness, and ethical concerns. (Aldoseri et al., 2023)

14 CONCLUSION

Summary of Evidence

This extensive review consolidates the findings of more than 150 peer-reviewed sources that explore the potential of education significantly transformer by AI and highlights key challenges that need to be urgently addressed. AI in education is a broad field that includes adaptive learning, personalized tutoring, intelligent assessment and learning prediction, learner profiling and more, ranging from technical systems to impacts of their adoption.

Key Insights

Transformative Potential: (Ayeni et al., 2024) AI-powered technologies have the potential to significantly improve academic performance by delivering enough challenge, personalizing the learning experience, and giving instant feedback. Nevertheless, there are common issues such as privacy, algorithmic bias, and equal access, among others that require careful control.

Critical Concerns: While excited about AI, there are critical voices calling for a balanced perspective on issues such as human connection, data privacy and security, algorithmic bias, transparency, and the implications of AI-generated content (Alzahrani, 2024). Improvements in AI transparency can help teachers in their professional development and contribute to improved student results.

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Equity and Access: (Capraro et al., 2024) Generative AI has potential to both exacerbate and ameliorate socioeconomic inequalities. Personalized learning can help to bridge digital divides and promote democratization of content creation and access. Intention to benefit those not served needs to be explicit as part of policy.

Teacher Centricity: Teacher should be primary player in the future of education, AI should augment. Effective implementation relies on a thorough professional development, ethics, and supportive policies.

Contributions

This paper does this by: - Summarizing extensive literature, geographically and disciplinary, while addressing critical research gaps in LMIC contexts and policy frameworks; - Proposing integrated frameworks that link technologies, processes, outcomes, and societal impacts; - Making actionable recommendations for a range of stakeholders.

Future Outlook

The future is promising new technology and guardrails to keep this technology from falling into the wrong hands. (Kamalov et al., 2023) Education needs to transcend corporate, neoliberal models for a vision of the human in relationality, embodiment, care and cultural sustainability. Global ethical guidelines for AI use, a philosophical approach to ethics, a risk-based regulatory framework, and key factors such as human agency oversight, robustness, privacy, transparency, diversity and nondiscrimination, societal wellbeing are all areas that must be considered when designing trustworthy AI. (Díaz-Rodríguez et al., 2023)

Final Scholarly Conclusion

AI offers immense potential to transform education by tailoring learning experiences, making them more accessible, and improving educational outcomes. However, this shift requires strong ethical oversight, policies that are inclusive, equitable allocation of resources, and a sense of human agency and dignity. Technology alone is not enough for success; it depends on our collective wisdom in using these tools judiciously, ensuring that they are used to promote the betterment of all students, the empowerment of teachers, and the improvement of sustainable equitable educational futures in our interdependent global community.

Graphical Outputs

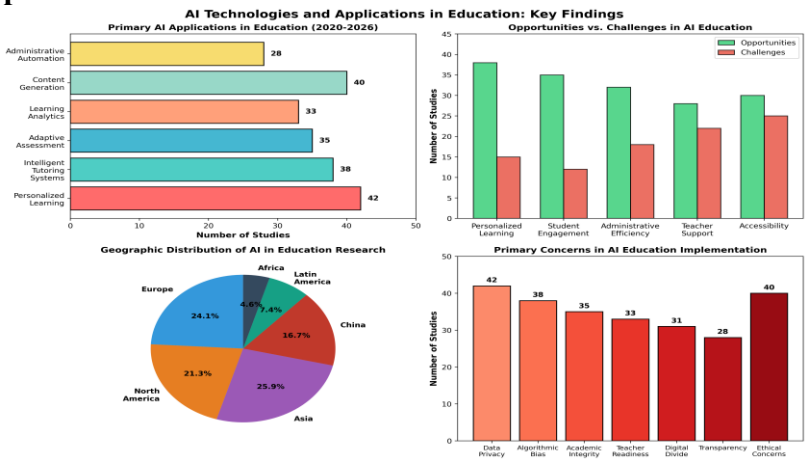

Figure 3. Ai Technologies and Application in Education: Key findings

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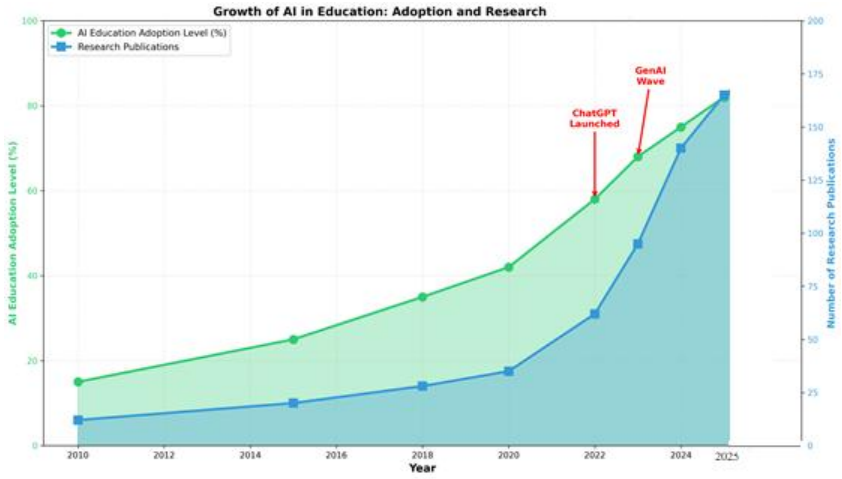

Figure 4. Growth of AI in Education: Adoption and Research

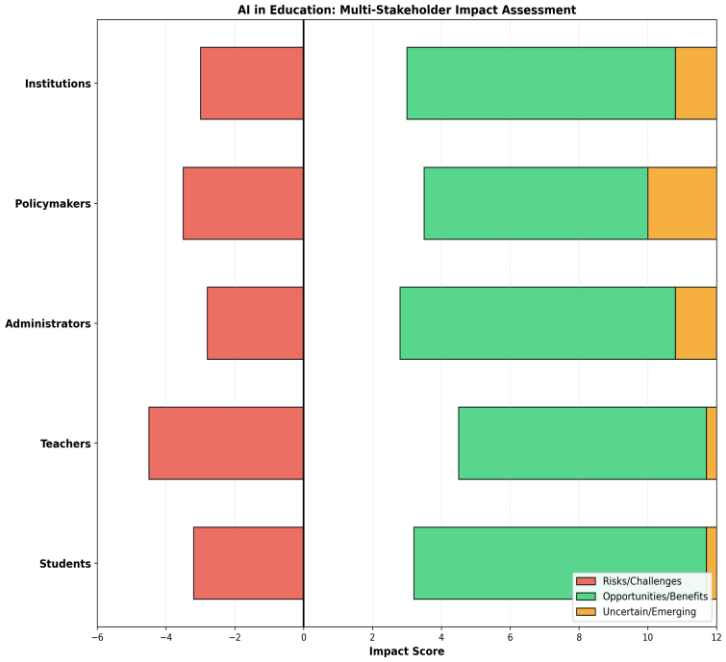

Figure 5. Ai in Education: Multi Stakeholder Impact Assessment

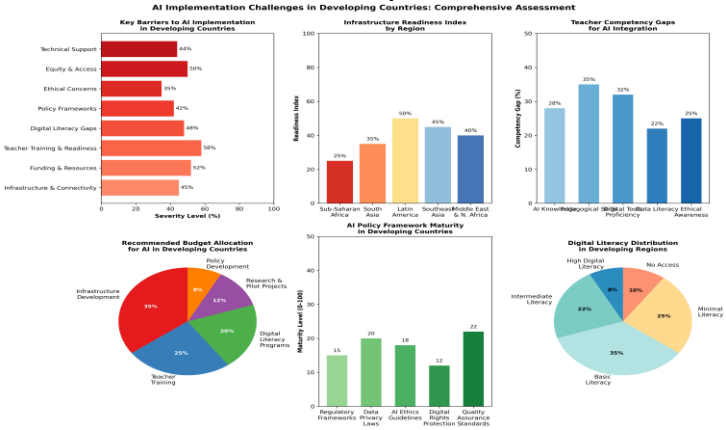

Figure 6. AI Implementation Challenges in Developing Countries

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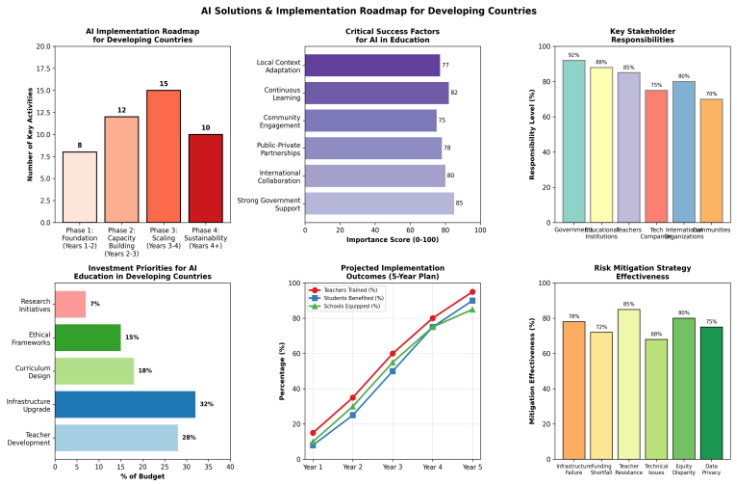

Figure 7. AI Solutions & Implementation Roadmap for Developing Countries

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