

Integrating AI in Education: Navigating UNESCO Global Guidelines, Emerging Trends, and Its Intersection with Sustainable Development Goals

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Abstract

This comprehensive review explores the integration of artificial intelligence (AI) in education, drawing from UNESCO guidelines and global recommendations from 2022 to 2024. The analysis highlights the transformative impact of AI on educational practices, focusing on its potential to enhance personalized learning, teacher training, and academic management, all of which are key in advancing Sustainable Development Goal 4 (SDG 4). However, the rapid development of AI technologies has outpaced policy debates, leading to the need for global and regional frameworks to guide the responsible integration of AI, ensuring equitable and human-centered educational advancements. Approximately 47% of academic institutions in high-income countries have implemented AI-driven tools by 2023, whereas only 8% have implemented AI-driven tools in low-income countries. Furthermore, the adoption of AI tools in classrooms is projected to grow with increasing AI technology implementation, with significant regional disparities that emphasize the need for targeted interventions. The review shows that to maximize the positive impact of AI on education, there is a pressing need for targeted investments in digital infrastructure, particularly in low-income regions. It also identifies future research directions and policy implications necessary for harmonizing AI innovation with ethical standards and its intersection with sustainable development goals.

Keywords: Education, Artificial intelligence, UNESCO, Sustainable development goals

1. Introduction

Artificial intelligence (AI) has rapidly emerged as a transformative force across various sectors, notably in education. Its potential to reshape traditional practices is evident, offering innovative solutions to long-standing challenges. In education, for instance, AI-driven technologies can facilitate more personalized learning experiences, improve teacher training, and enhance the management of educational systems (Al-Momani & Ramayah, 2024; Chaudhry & Kazim, 2022; Crompton & Burke, 2023; Mao et al., 2024). Recent data indicate that approximately 40% of organizations report significant value from AI deployment in learning processes, whereas another 40% report moderate value with a growing influence of AI in educational contexts (HolonIQ, 2023).

The AI index, developed by the Stanford Institute for Human-Centered Artificial Intelligence (HAI) (Lynch, 2023), provides a detailed analysis of the current state of

artificial intelligence. The report highlights that large language models (LLMs) have seen exponential growth, with costs increasing from tens of thousands in 2019 to millions of dollars in 2023. On the other hand, the GPT-3 model was identified as consuming 1,287 MWh of power during training, equivalent to the annual energy consumption of an average U.S. household for 120 years. AI-related positions have seen a notable increase in the U.S., with California leading with 142,154 AI-related job postings, followed by Texas with 66,624, and New York with 43,899. Globally, China's dominance in industrial robotics is evident, with the country representing 51.8% of all installations worldwide in 2021. The U.S. federal government also continued to increase its investment in AI research, with the fiscal year 2022 budget allocating \$1.7 billion to AI R&D, a 13% increase from the previous year, and a 209% increase since 2018 (Lynch, 2023).

The role of AI is particularly significant in advancing Sustainable Development Goal 4 (SDG 4), which aims to ensure inclusive and equitable quality education for all. However, the rapid development of AI technologies also presents several ethical and regulatory challenges that have, thus far, outpaced policy debates. These challenges include concerns about data privacy, algorithmic bias, and the potential for AI to reinforce existing inequalities (Kabudi, 2022). For example, nearly 54% of organizations cite the lack of skilled AI talent as a major barrier to AI adoption in education, further complicating efforts to harness AI's full potential (HolonIQ, 2023).

UNESCO, which recognizes the profound impact of AI, has committed to supporting Member States on AI while ensuring that its application in education is guided by principles of inclusion, equity, and human-centeredness. UNESCO's efforts are part of a broader mandate to promote the ethical use of AI, addressing inequalities in access to knowledge, research, and cultural diversity. To this end, UNESCO has developed several key publications, including the Beijing Consensus and the Artificial Intelligence and Education: Guidance for Policy-makers. These documents aim to equip education policymakers with the tools and knowledge needed to navigate the opportunities and challenges posed by AI. Furthermore, the Global AI Ethics and Governance Observatory serves as a crucial resource for stakeholders seeking best practices in ethical AI deployment (Miao, Holmes, Huang, et al., 2021a; UNESCO, 2017, 2023d).

As AI continues to evolve, its influence extends beyond education. However, these developments also raise critical ethical concerns, particularly related to bias, data privacy, and the potential for AI to reinforce existing inequalities. UNESCO's Recommendation on the Ethics of Artificial Intelligence, adopted by 193 Member States in 2021, provides a global framework to address these challenges, ensuring that AI technologies are developed and deployed responsibly, taking into account ethical considerations (Lynch, 2023; UNESCO, 2022c, 2023d).

In addition to the guidelines provided by UNESCO, the Horizon Report 2024 (Teaching and Learning Edition), recently released by the Information Technology in Higher Education Association of the United States (EDUCAUSE), highlights 20 macrotrends, including significant technological advancements that are expected to influence teaching and learning in the coming years. With the integration of AI becoming an inevitable trend, the report also predicts several future development scenarios, including the potential for AI to drive personalized education (Educase, 2024). Additionally, there is increasing recognition that frameworks such as environmental,

social, and corporate governance (ESG) can enhance the management of enterprises in AI and attract more investment and cooperation opportunities, which aligns with SDGs 3, 8, 9, 11, and 12 (Sætra, 2023).

1.1 Why a Global Recommendation for the Use of AI in Education is Needed?

AI systems, if not carefully designed and deployed, pose risks such as biases in information and so-called deepfakes, among others. Moreover, the transformative power of AI has the potential to widen the technological divide, disproportionately impacting marginalized communities; therefore, actionable strategies should be implemented to ensure that the technologies reach all the communities (Barrett, 2023).

Recognizing the urgency of these concerns, UNESCO published the first-ever global standard on AI ethics: the “Recommendation on the Ethics of Artificial Intelligence.” Adopted by 193 Member States in November 2021, this framework seeks to ensure that AI technologies are developed and utilized in ways that respect and promote human rights and dignity. Central to the Recommendation are four core values: respect for human rights and human dignity; the promotion of peaceful, just, and interconnected societies; the commitment to diversity and inclusiveness; and the flourishing of the environment and ecosystems (UNESCO, 2021b).

In addition to these core values, the Recommendation outlines ten principles that emphasize a human rights-centered approach to AI ethics. These include proportionality and the prevention of harm, safety and security; the right to privacy and data protection; and the importance of transparency, explainability, and human oversight. The recommendation also addresses the need for multistakeholder and adaptive governance, ensuring that AI systems are developed in a manner that is fair, nondiscriminatory, and aligned with the principles of sustainability (UNESCO, 2021b).

The implementation of these guidelines is particularly critical in the field of education, where AI has the potential to drive practices and accelerate progress toward achieving the United Nations SDGs. However, this potential can be realized only if AI is harnessed responsibly, with careful attention to the ethical implications of its deployment (Nazer et al., 2023; UNESCO, 2021b).

1.2 Brief introduction of AI concepts and technologies

Understanding AI involves unpacking its layers—from foundational concepts such as artificial intelligence (AI) and machine learning (ML) to more complex structures such as neural networks (NNs), deep learning (DL), and large language models (LLMs) (Figure 1) (Goodfellow et al., 2016; Hinton et al., 2006; LeCun et al., 2015; Nielsen, 2015; L. Ramos et al., 2023). Machine learning (ML) is a subset of AI where algorithms learn from data, allowing systems to improve over time without explicit programming. Within ML, neural networks (NNs) play a crucial role by mimicking the structure of the human brain to process and interpret complex data. Deep learning (DL), a more advanced form of neural networks, involves multiple layers that enable systems to handle vast amounts of data, making it essential for tasks such as image and speech recognition (Marquez et al., 2023; Shneiderman, 2020; Vaswani et al., 2017).

Large Language Models (LLMs), a specialized form of DL, have gained significant attention for their ability to process and generate human language with remarkable accuracy. These models, built on transformer architectures, are capable of understanding context and generating coherent text, making them indispensable in applications ranging from chatbots to automated content creation. Recent advancements in LLMs have led to their widespread adoption across several industries (Z. Bin Akhtar, 2024; Kumar, 2024). Figure 2 shows the various techniques used within AI. Supervised learning trains from labeled data for tasks such as spam detection and image classification, and unsupervised learning identifies hidden patterns in unlabeled data. Reinforcement learning is shown to interact with the environment to optimize actions, exemplified by autonomous robotics and game playing. Generative adversarial networks (GANs) represent another transformative AI technology. GANs consist of two neural networks—the generator and the discriminator—that work together to produce highly realistic data, such as images, videos, and even audio. GANs have been particularly influential in creative industries, enabling applications such as AI-generated art, deepfakes, and advanced image editing (Casas et al., 2023; L. T. Ramos & Sappa, 2024). Additionally, deep learning (DL) extends neural networks with multiple layers for complex pattern recognition. Finally, neural networks (NNs) are described as mimicking the brain structure, enabling tasks such as handwriting recognition and speech processing.

Figure 1. Foundational concepts of artificial intelligence (AI).

Figure 2. Techniques in artificial intelligence (AI).

Figure 3 presents a comprehensive overview of various AI applications. NLP uses AI techniques such as machine learning (ML), DL, regression, and k-means for interpreting and generating text, with applications such as Otter, Google BERT, and OpenAI GPT. Speech recognition, which is applied to spoken words in personal assistants such as Alibaba Cloud and Google Assistant, uses deep learning techniques, specifically recurrent neural networks (LSTMs). On the other hand, Autonomous Agents, such as Woebot and Boston Dynamics' Spot, are driven by AI techniques, including GOF AI, DL, and reinforcement learning, which function as virtual companions, smart robots, and drones. Affect detection employs Bayesian networks and DL to analyze sentiment in text and facial expressions, with examples such as Affectiva and the Microsoft Azure Emotion API. Image recognition and processing, which are used in tasks such as facial recognition and autonomous vehicles with tools such as Google Lens and Tesla Autopilot, rely on deep learning and convolutional neural networks (CNNs). Data mining for prediction, which is essential for predicting outcomes in healthcare, weather forecasting, and fraud detection, uses supervised learning, DL, and support vector machines, as demonstrated by IBM Watson Health and Google DeepMind's AlphaFold. Finally, artificial creativity involves AI systems that generate new content, such as images and stories, using generative adversarial networks (GANs) and autoregressive models, with notable examples being OpenAI's DALL-E and GPT-4o, Claude 3.5, and PaLM 2, among others (M. N. Akhtar et al., 2024; Grubaugh et al., 2023; Kumar, 2024).

Figure 3. Applications and techniques in artificial intelligence (AI)

This critical review aims to explore the current state of AI in education and analyze the global guidelines provided by UNESCO between 2022 and 2024, such as UNESCO's recommendation for AI policy development, highlighting the emerging trends and ethical considerations that must be addressed to ensure that AI contributes to a more equitable and sustainable future (UNESCO, 2021a). This review will also examine the intersection of AI with sustainable development goals, particularly SDG 4, and identify future research directions and policy implications necessary for aligning AI education with global ethical standards.

2. UNESCO and Global Guidelines on AI in Education

The analysis of UNESCO publications on AI from 2022-2024 is shown in Table 1. There is a strong interconnected focus on ethical AI deployment, especially within educational contexts, which is represented graphically in Figure 4. These documents collectively advocate for a human-centered approach to AI, emphasizing transparency, fairness, and global collaboration. The alignment of these themes across different publications highlights UNESCO's strategic efforts to guide AI development in a way that supports global educational goals and upholds ethical standards. Thirty-five percent of the documents focus explicitly on AI ethics, reflecting the growing concern about the ethical implications of AI in various sectors, particularly education. Forty-five percent of the documents focus on AI's role in education, indicating UNESCO's commitment to using AI to achieve SDG 4 (quality education). Twenty percent of the documents emphasize the need for global cooperation in AI policy-making, highlighting UNESCO's role in fostering international dialog and collaboration. All the documents converge on the theme of ethical AI in education, stressing the need for AI systems that are not only effective but also fair, transparent, and aligned with human rights (Miao & Holmes, 2023; UNESCO, 2019a, 2022b, 2023f, 2023i, 2023c, 2023g). There is a strong interconnection between documents that advocate for global policy alignment, with the "UNESCO Recommendation on the Ethics of AI" (UNESCO, 2021b) serving as a foundational guideline that informs other documents in Table 1. Figure 4 shows the outcomes of the Global Meeting of Ministers of Education, which focused on the integration of AI in educational frameworks. The key areas include the development of generative AI guidelines, the establishment of teacher and student competency frameworks, and the emphasis on critical thinking and interactive learning (UNESCO, 2023a). The importance of transparency and data privacy in AI applications is also highlighted, along with the adaptation of policies to ensure the ethical implementation of AI in education. These elements collectively contribute to the ongoing efforts to align global educational practices with the ethical standards set by international bodies. The UNESCO publications from 2022 to 2024 reflect a growing global focus on the integration of AI in education, particularly through ethical and sustainable practices. According to recent data, the adoption of AI in educational settings has substantially increased, with approximately 47% of educational institutions in high-income countries implementing AI-driven tools by 2023, compared with only 8% in low-income countries (Miao & Holmes, 2023; UNESCO, 2023f, 2023i, 2023c, 2023g).

Moreover, the implementation of AI tools in classrooms is projected to grow with the rapid expansion of AI usage. However, adoption rates vary significantly across regions. For instance, Europe and North America have the highest adoption rates, with over 60% of institutions integrating AI at some capacity, whereas Sub-Saharan Africa and parts of South Asia lag behind with less than 15% adoption (UNESCO, 2022a, 2023f). The analysis of UNESCO publications reveals that 45% of the documents specifically focus on AI's role in education, reflecting a strong commitment to leveraging AI to achieve SDG 4. Within these documents, there is a clear emphasis on developing global guidelines to ensure that AI's integration into education systems is both effective and equitable. However, the data suggest that the impact of these guidelines is uneven, with higher adherence observed in regions with more robust educational infrastructure (UNESCO, 2023f, 2023i, 2023g). Considering these statistics, UNESCO's role in fostering international collaboration becomes even more critical. The organization's efforts to promote global AI policy alignment are evident in the fact that 20% of the analyzed documents emphasize the need for such cooperation (Chan, 2023a; Francisco & Linnér, 2023a; Miao, Holmes, Huang, et al., 2021b).

Table 1. UNESCO publications from 2022-2024 on AI.

Title	Year	Primary Focus	Description	Ref
UNESCO Recommendation on the Ethics of AI	2021	AI Ethics	A foundational document providing ethical guidelines for the development and use of AI, emphasizing human rights, sustainability, and fairness.	(UNESCO, 2021c)
AI and Education: Guidance for Policy-Makers	2021	AI in Education	Outlines emerging practices in AI and education, discusses challenges, and provides policy recommendations to align AI usage with SDG 4 (Quality Education).	(Miao, Holmes, Huang, et al., 2021b)
Preliminary Study on the Ethics of AI	2019	AI in Higher Education	An early exploration of the ethical implications of AI, addressing its potential to impact human rights, governance, and societal values.	(UNESCO, 2019a)
Harnessing AI in Higher Education	2023	Generative AI in Education	A quick start guide focused on the application of AI in higher education, addressing ethical concerns, practical steps for integration, and the potential impact on teaching, learning, and administration.	(UNESCO, 2023g)
ChatGPT and Higher Education	2023	Generative AI, Research Impact	Discusses the role of ChatGPT in higher education, including its benefits, challenges, and ethical considerations.	(UNESCO, 2023c)
Generative AI in Education and Research	2023	Global Policy Collaboration	Explores the role of generative AI in education and research, examining its potential to enhance learning experiences and drive innovation while addressing ethical and practical concerns.	(Miao & Holmes, 2023)

Figure 4. AI Policy Adaptation in Global Education.

2.1 Guidelines on AI and Their Intersection with Sustainable Development Goals (SDGs)

UNESCO has developed several key guidelines that align closely with the United Nations SDGs, emphasizing the importance of responsible AI deployment (Miao, Holmes, Huang, et al., 2021a; UNESCO, 2023a). These include a human-centered approach and ethical AI governance for developing global standards, while transparency ensures trust in AI systems. Equitable access to AI requires investments in infrastructure. Finally, AI implementation should be performed to ensure environmental sustainability (Table 2) (Sætra, 2023; van Wynsberghe, 2021). Stakeholders such as policymakers and developers must work together to ensure that AI serves as a tool to promote quality education for all. The lack of a global consensus on AI ethics presents challenges in creating a standardized approach to AI governance (Corrêa et al., 2023; Francisco & Linnér, 2023b). To address this, international guidelines that align AI deployment with ethical principles must be developed and adopted (Floridi, 2019). UNESCO and governments play a key role in this process, ensuring that AI technologies contribute to peace, justice, and strong institutions globally. AI systems often operate in opaque ways, leading to mistrust and ethical concerns. It is essential to mandate transparency in AI decision-making processes, ensuring that these systems are explainable and auditable.

This requires collaboration between tech companies and regulators to build public confidence in AI technologies. The digital divide poses a significant barrier to the equitable distribution of AI benefits, potentially excluding marginalized groups from accessing these technologies. To overcome this, investment in infrastructure and education is necessary to ensure that all communities can benefit from AI. Governments and NGOs must work together to bridge this gap, with a focus on reducing inequalities in access to technology and education. The environmental impact of AI, particularly its high energy consumption, raises concerns about its sustainability. To address this, AI systems should be designed with sustainability in mind, promoting energy-efficient algorithms and green practices. Environmental agencies must be involved in ensuring that AI contributes positively to environmental sustainability and climate action (Francisco & Linnér, 2023b; Mazzi et al., 2023; Sætra, 2023; van Wynsberghe, 2021).

The implementation of such recommendations requires the involvement of stakeholders and institutions, including those related to AI ethics and overseeing, as presented in Table 3. Different stakeholders, such as governments, academics, the private sector, and civil society, collaborate to advance AI ethics. Governments focus on policy formulation and enforcement through multilateral forums and bilateral agreements, whereas academia drives research and education through collaboration and consortia. The private sector innovates and ensures ethical AI deployment via public–private partnerships and industry standards. Civil society, through NGOs and advocacy groups, plays a critical role in monitoring, holding entities accountable, and promoting ethical AI use. Each stakeholder group works in tandem to achieve the

overarching goal of ethical AI integration across sectors (Corrêa et al., 2023; Francisco & Linnér, 2023b; Mazzi et al., 2023).

Table 2. UNESCO recommendations for AI implementation

Recommendation	Challenges	How to Apply	Stakeholders Involved	Impact Areas	SDG Affected
Human-Centered AI	AI systems risk reinforcing biases and widening inequalities.	Implement AI systems with an explicit focus on equity, ensuring diverse datasets and inclusive algorithms.	Policymakers, Developers	Education, Cultural Diversity	SDG 4 (Quality Education)
Ethical AI Governance	Lack of global consensus on AI ethics and governance.	Develop and adopt international guidelines that align AI deployment with ethical principles.	UNESCO, Governments	Global AI Policy, Ethics	SDG 16 (Peace, Justice, Strong Institutions)
Transparency and Explainability	AI systems can be opaque, leading to mistrust and ethical concerns.	Mandate transparency in AI decision-making processes, ensuring systems are explainable and auditable.	Tech Companies, Regulators	Trust, Public Confidence	SDG 16 (Peace, Justice, Strong Institutions)
Equitable Access to AI	Digital divides may exclude marginalized groups from AI benefits.	Invest in infrastructure and education to ensure all communities have access to AI technologies.	Governments, NGOs	Education, Technology Access	SDG 10 (Reduced Inequalities)
Environmental Sustainability	High energy consumption and environmental impact of AI technologies.	Design AI systems with sustainability in mind, promoting energy-efficient algorithms and green practices.	Environmental Agencies	Sustainability, Environmental Impact	SDG 13 (Climate Action)

Table 3. Organizations and institutions related to AI ethics and overseeing

Entity/Organization	Governance Role	Government Institutions Involved
UNESCO	Provides global AI ethics guidelines	Member States' education and technology ministries
Global AI Ethics and Governance Observatory	A central hub for AI ethics resources and practices	UNESCO, International Organizations
Member States Governments	Implement AI policies based on UNESCO guidelines	National education, science, and technology ministries
AI Ethics and Governance Lab	Provides research, toolkits, and best practices	Collaboration with international and national institutions
United Nations (UN)	Supports international cooperation on AI ethics	Member States, UN agencies
National Ethics Commissions	Ensure ethical compliance in AI implementations	National governments

2.2 Actionable Policies and Implementation Strategies

While the foundational values and principles provide the ethical framework for AI, recent movements in AI ethics have highlighted the necessity of moving beyond high-level guidelines toward practical, actionable strategies. UNESCO's recommendation (Miao, Holmes, Huang, et al., 2021a; UNESCO, 2021b, 2022c, 2023a, 2023d) addresses this need by outlining eleven key areas for policy actions, offering concrete steps for Member States to ensure the responsible development and deployment of AI (Table 4).

Table 4. The Recommendation identifies several critical policy areas where Member States can make meaningful strides toward ethical AI development

Category	Characteristics of critical policy areas
Ethical Governance and Stewardship	<ul style="list-style-type: none">- Inclusive, transparent, and multidisciplinary governance structures.- Emphasis on enforcement, redress, and proactive governance.
Economy and Labor	<ul style="list-style-type: none">- Addressing the impact of AI on the labor market.- Integrating AI-related skills into educational curricula to close the skill gap and boost market competition.
Data Policy	<ul style="list-style-type: none">- Establishing robust data governance mechanisms to protect individual privacy.- Developing quality datasets for AI training and development.
Health and Social Wellbeing	<ul style="list-style-type: none">- Utilizing AI to improve healthcare delivery and address global health risks.- Ensuring AI applications in healthcare are safe, effective, and ethically sound.
Education and Research	<ul style="list-style-type: none">- Promoting AI literacy and ethical awareness in education.- Encouraging research initiatives on AI ethics and its impact on society.
Gender Equality	<ul style="list-style-type: none">- Maximizing AI's potential to advance gender equality.- Implementing dedicated funding and policies to support women and girls, particularly in STEM fields.
Environment and Ecosystems	<ul style="list-style-type: none">- Assessing and mitigating the environmental impacts of AI technologies.- Using AI to support environmental sustainability and climate action.
Implementation Tools	<ul style="list-style-type: none">- Readiness Assessment Methodology (RAM): Assesses preparedness to implement AI policies and identifies gaps.- Ethical Impact Assessment (EIA): Evaluates potential impacts of AI systems, ensuring collaboration with communities for ethical deployment.

These actionable policies, grounded in the core values and principles of UNESCO's recommendations, provide a roadmap for Member States to foster responsible AI innovation. Governments, the private sector, and civil society can work together to ensure that AI contributes to a more equitable, inclusive, and sustainable future by implementing these strategies. Figure 5 presents the diverse policy areas where AI technologies can influence and where AI oversight can be implemented. Figure 6 shows an example of one of the instruments for the assessment of the implementation of AI policies, the Readiness Assessment Methodology (RAM) (UNESCO, 2023h), starting with initial planning and coordination to define the scope and allocate resources. Stakeholder engagement follows, ensuring broad involvement from relevant parties. Data collection and analysis across five dimensions provide the foundation for subsequent report preparation, which summarizes findings and offers recommendations. An implementation plan is then developed, followed by capacity building and training to enhance AI governance. Finally, monitoring and evaluation

ensure the continuous improvement and adaptation of AI policies on the basis of the RAM findings (UNESCO, 2023h).

Figure 5. Diverse policy areas where AI technologies can influence and where AI overseeing could be implemented. Reproduced from (UNESCO, 2021b, 2024a)

Figure 6. Steps to implement the readability assessment methodology (RAM)

2.3 Case studies on the implementation of AI in Education

UNESCO's guidelines on AI in education have been instrumental in shaping global discourse and policy development. However, the implementation of these guidelines varies significantly across different regions, reflecting diverse educational, cultural, and technological landscapes. The effective integration of AI into education requires not only high-level guidelines but also practical, actionable strategies that can be implemented at the national and local levels. UNESCO's recommendation on AI outlines several key policy areas where Member States can make meaningful progress toward ethical AI development (Truong et al., 2021; UNESCO, 2021b; Zhong, 2024).

2.3.1 Case Study 1: Ethical AI Governance in the European Union

The European Union's approach to AI governance is a leading example of how international guidelines can be translated into actionable policies. The EU's General Data Protection Regulation (GDPR), implemented in 2018, serves as a cornerstone for data protection and transparency in AI systems. By establishing robust data governance mechanisms, the GDPR has set a global standard for ensuring that AI systems respect individual privacy and are transparent in their decision-making processes (Marelli & Testa, 2018; Truong et al., 2021).

In the context of education, the GDPR has been particularly impactful in protecting student data. For example, in Germany, the implementation of AI-driven learning management systems (LMSs) in schools was accompanied by stringent data protection measures in line with the GDPR. These measures ensured that the student data were handled securely and that the AI algorithms used in the LMS were transparent and explainable. The success of the GDPR in promoting ethical AI practices in education highlights the importance of strong governance frameworks that prioritize privacy and transparency (Barezzani, 2019).

2.3.2 Case Study 2: Promotion of Equitable Access to AI in Singapore

Singapore's "SkillsFuture" initiative is an exemplary case of how targeted investments in education and infrastructure can promote equitable access to AI. Launched in 2015, SkillsFuture aims to provide lifelong learning opportunities for all Singaporeans, with a strong emphasis on digital skills and AI literacy. The initiative offers a wide range of

programs, from AI boot camps for students to professional development courses for educators (Chan, 2023b; Fung et al., 2021b; Lee et al., 2023).

By 2022, over 500,000 Singaporeans had participated in SkillsFuture programs, with a significant portion of these programs focused on AI and digital literacy. The success of SkillsFuture can be attributed to its inclusive approach, which ensures that individuals from all backgrounds, including those from disadvantaged communities, have access to AI education (Fung et al., 2021a).

2.3.3 Case Study 3: AI and Environmental Sustainability in Canada

Canada's "Pan-Canadian Artificial Intelligence Strategy," launched in 2017 (Attard-Frost et al., 2024; CIFAR, 2024), includes a strong focus on the environmental impact of AI technologies. This strategy promotes the development of AI systems that are not only effective but also environmentally sustainable. One of the key components of this strategy is the encouragement of green AI practices, such as the development of energy-efficient algorithms and the use of renewable energy sources in AI data centers (Attard-Frost et al., 2024).

The University of Toronto's Vector Institute, a leading AI research hub in Canada, has been at the forefront of promoting sustainable AI practices (VI, n.d.). The Institute has developed several AI models that significantly reduce energy consumption without compromising performance. These models are being utilized in educational settings, where they support a variety of applications, from personalized learning to educational data analytics, while trying to comply with the principles of decreasing the environmental footprint.

2.3.4 Case Study 4: Inclusive AI Education in Rwanda

Rwanda's approach to AI in education demonstrates how inclusive policies can bridge the digital divide in developing countries. The "Smart Africa" initiative, led by the Rwandan government in partnership with UNESCO, focuses on integrating digital technologies, including AI, into the education system. The initiative aims to provide equitable access to AI tools for students in rural and underserved areas (Matseke, 2023; Yedder, 2023).

By 2023, the initiative had provided more than 10,000 students with access to AI-driven educational resources, including adaptive learning platforms and AI-powered tutoring systems. The success of the Smart Africa initiative is due in part to its focus on the local context and its collaboration with international organizations such as UNESCO.

3. Overview of AI's role in education and its intersection with SDG 4

AI should be developed and deployed with a human-centered approach, ensuring that it supports human rights and is ethically sound. Examples such as AI for Humanity (France) and the EU Ethics Guidelines for Trustworthy AI demonstrate frameworks that prioritize ethical AI use, ensuring transparency, fairness, and accountability. These frameworks guide policymakers in creating AI systems that respect human dignity and enhance educational outcomes (*AI for Humanity*, 2009; European

Commission, 2019). Effective AI policies require input from diverse disciplines and stakeholders. The elements of the AI course and the high-level expert group on AI serve as models for engaging interdisciplinary expertise in policy planning. These initiatives highlight the importance of collaboration among educators, AI developers, and policymakers to create AI systems that are responsive to educational needs and societal values (Elements of AI, 2024; European Commission, n.d.).

To ensure that AI benefits all students, policies must address biases and promote inclusion. Digital Bangladesh and UNESCO's 'I'd blush if I could' are examples of initiatives aimed at bridging digital divides and addressing gender biases in AI. These programs illustrate how targeted policies can promote equitable access to AI tools, ensuring that marginalized groups are not left behind in the AI revolution (M. West et al., 2019). AI can significantly enhance education management systems (EMISs) and learning management systems (LMSs). The OU Analyse and Zhixue platforms demonstrate how AI can be used to predict student outcomes and provide personalized learning experiences (OU Analyse, 2024; ZHIXUE, 2024). These examples show the potential of AI to streamline educational processes, making them more efficient and responsive to student needs.

Teachers must be supported in the integration of AI into their teaching practices. The UNESCO ICT Competency Framework provides guidelines for developing the necessary skills, whereas resources from the International Society for Technology in Education (ISTE) offer practical tools for educators. These initiatives emphasize the need to empower teachers as AI becomes increasingly prevalent in classrooms (UNESCO, 2018). AI has the potential to support lifelong learning by providing diverse educational pathways and tracking learning outcomes. Initiatives such as SkillsFuture and OpenCerts from Singapore illustrate how AI can be used to support continuous education and credentialing across different contexts. These examples demonstrate the role of AI in creating flexible and adaptive learning environments that cater to learners of all ages (OpenCerts, 2024; SkillsFuture, 2024). Integrating AI-related skills into educational curricula is essential for preparing students for the future. The CEDEFOP Skills Forecast and the Wekinator provide tools for anticipating future skill demands and teaching AI-related competencies (Cedefop, 2024; Rebecca Fiebrink, 2024).

To ensure the effectiveness of AI in education, rigorous testing and evaluation are needed. Projects such as ITalk2Learn and Squirrel AI Learning are examples of AI systems that have undergone pilot testing to assess their impact on learning outcomes. These initiatives highlight the importance of building a robust evidence base to inform policy decisions and scale successful AI applications (ITalk2Learn, 2024; Squirrel AI Learning, 2024). Promoting the local development of AI technologies is crucial for ensuring that AI tools are relevant and effective in different cultural and educational contexts. IBM Research–Africa and Next AI in Canada are examples of initiatives that support the development of local AI talent and innovations. These programs illustrate the need for policies that encourage local AI development and ensure that AI tools are tailored to meet the specific needs of local populations (IBM, 2024; NEXT, 2024). The incorporation of AI into education requires addressing strategic priorities and ethical considerations and fostering local innovation. The interconnected examples provided illustrate how these policies can be operationalized, offering practical models for countries looking to harness the potential

of AI in education while safeguarding human rights and promoting inclusive, equitable, and sustainable educational practices (Miao, Holmes, Ronghuai Huang, et al., 2021).

SDG 4 sets an ambitious target to ensure inclusive and equitable quality education for all by 2030. The integration of artificial intelligence (AI) into education offers significant potential to advance this goal, particularly in areas such as personalized learning, teacher training, and educational management. However, to fully realize this potential, AI must be deployed in ways that address the specific targets outlined within SDG 4 (Kabudi, 2022; Mazzi et al., 2023).

Target 4.1: Ensuring Free, Equitable, and Quality Primary and Secondary Education

AI-driven tools, such as intelligent tutoring systems, have shown success in improving learning outcomes. For example, AI-powered adaptive learning platforms can provide personalized instruction, with studies indicating a 20–30% improvement in learning efficiency in certain subjects, such as math. However, the digital divide poses a major barrier, especially in low-income countries where limited access to technology and the internet hampers educational equity. The Unicef "Giga" initiative aims to connect all schools to the internet by 2030, addressing this disparity (Unicef, 2024).

Target 4.4: Increasing the Number of Youths and Adults with Relevant Skills for Employment

AI has the potential to significantly increase the number of youth and adults with relevant skills for employment by providing targeted training programs and lifelong learning opportunities. For example, AI-powered career guidance systems can help students identify suitable career paths on the basis of their skills and interests, whereas AI-driven educational platforms can offer customized training programs that align with labor market demands. In India, the government's "Skill India" initiative, supported by AI technologies, has trained over 5 million people in digital and technical skills since its launch in 2015 (Chitturu, 2024). The initiative's success highlights AI's ability to scale educational opportunities and equip learners with the skills needed to thrive in an AI-driven economy. UNESCO supports similar initiatives globally, advocating for AI's role in workforce development and the achievement of Target 4.4.

Target 4.5: Eliminating Gender Disparities in Education

Eliminating gender disparities in education is a critical component of SDG 4, and AI can contribute to this goal by promoting gender-inclusive learning environments. AI tools can be designed to be free from gender biases, offering equal opportunities for girls and boys to engage with technology and STEM subjects. However, significant challenges remain (UNESCO, 2023b). According to the World Economic Forum, women represent only 22% of AI professionals globally, reflecting broader gender disparities in STEM education (WEF, 2022). UNESCO's "Girls in ICT Day" initiative aims to address this gap by encouraging more girls to pursue careers in technology and AI. Since its inception, the initiative has reached girls in 170 countries, providing them with the skills and confidence to engage in AI-related fields (UNESCO, 2024c).

Target 4.6: Ensuring Literacy and Numeracy for All

AI can support global literacy and numeracy efforts by providing personalized learning tools that cater to the needs of learners at all levels (Pataranutaporn et al., 2021). AI-driven literacy programs, such as UNESCO’s “Global Education Coalition” initiative, utilize AI to reach marginalized populations, including refugees and out-of-school children (UNESCO, 2024e). Through partnerships with tech companies, this initiative has developed AI-powered apps that provide literacy training in multiple languages, reaching over 850,000 youths to develop skills for employment (UNESCO, 2024b).

4. Challenges and Policy Responses to AI in Education

Harnessing AI to achieve SDG 4 presents several challenges that require strategic responses to ensure that the technology benefits all learners equitably. Addressing data ethics and biases is crucial to maintaining fairness and protecting privacy. Promoting gender-equitable AI and supporting women in the AI workforce are essential for advancing gender equality. Furthermore, continuous research and monitoring are needed to evaluate the impact of AI on education. Finally, safeguarding teacher roles and learner agency in AI-rich environments is critical to fostering a human-centered educational system.

Various national and regional strategies address the integration of AI into education (Table 5) (OECD Digital Education Outlook 2023, 2023). Countries have adopted independent, integrated, or thematic approaches to policy-making. The key objectives include improving educational opportunities, enhancing digital literacy, fostering lifelong learning, and adapting education systems to the Fourth Industrial Revolution. Financial commitments vary, with some countries investing significantly in AI research and education, whereas others focus on curriculum innovation and data privacy. The expected outcomes range from personalized learning and intelligent education systems to increased AI talent and improved digital competencies among students.

Table 5. Policy responses to AI in education (OECD Digital Education Outlook 2023, 2023)

Country/Region	Policy/Strategy	Approach	Outcomes/Expected Impact
United States	National Artificial Intelligence Research and Development Strategic Plan	Independent	Universal access to AI-enhanced learning technologies, improved educational outcomes, and lifelong learning opportunities.
China	New-Generation Artificial Intelligence Development Plan	Independent	Intelligent education systems, personalized learning for all students, and enhanced educational resources and management.
European Union	General Data Protection Regulation (GDPR)	Thematic	Enhanced data privacy and security, standardized data protection across Europe.
Republic of Korea	Mid- to Long-Term Plan for Intelligent	Integrated	Increased AI talent pool, strengthened AI research, and innovation in education.

	Information Society		
Argentina	Aprender Conectados	Integrated	Enhanced digital literacy, widespread adoption of computational thinking, and preparedness for the digital economy.
Malta	Toward an AI Strategy	Independent	Modernized education system, AI-driven curriculum, and improved digital literacy among students.
Malaysia	#mydigitalmaker	Integrated	Enhanced digital competence among students, integration of computational thinking in the national curriculum.
Estonia	ProgeTiger Programme	Thematic	Widespread digital literacy, early adoption of coding and robotics, and readiness for future technology challenges.
Singapore	Code@SG Movement	Thematic	Development of national computational thinking capabilities, early integration of coding skills in education.
United Arab Emirates	UAE Strategy for Artificial Intelligence	Independent	Cost-effective education system, AI-driven learning improvements, and integration of AI across multiple sectors.

While AI holds immense potential to transform education, it also presents significant challenges, particularly in terms of gender equity and inclusion. The digital divide and the underrepresentation of women and marginalized groups in AI education and careers pose serious barriers to achieving equitable outcomes.

4.1 Gender Gap in AI Education and Careers

Recent studies indicate that women are significantly underrepresented in AI-related fields. Globally, only 22% of AI professionals are women, a disparity that reflects broader gender inequalities in STEM education. In educational contexts, this gender gap is evident at multiple levels (WEF, 2018). For example, in computer science courses, which serve as a gateway to AI, women account for only 33% of researchers worldwide (UNESCO, 2019b). This underrepresentation is even more pronounced in leadership roles within AI research and development; only 18% of authors at leading AI conferences and 80% of AI professors are men (S. M. West, 2019).

The gender gap in AI is not just a matter of representation but also of opportunity and impact. Women and marginalized groups often lack access to the same educational resources and opportunities as their male counterparts do, leading to disparities in skills and knowledge. This digital divide is particularly pronounced in low-income countries, where access to technology and quality education is limited.

UNESCO has recognized the critical need to address these disparities and has launched several initiatives aimed at promoting gender equity in AI education. One such initiative is the "Cracking the Code: Girls' and Women's Education in STEM" program, which seeks to increase female participation in STEM fields, including AI. By 2023, this program had reached over 2 million girls in 30 countries, providing them with the tools and resources needed to pursue careers in STEM and AI (UNESCO, 2019b).

Additionally, UNESCO's "Women4Ethical" initiative focuses on integrating gender perspectives into AI policies and practices (UNESCO, 2023b). This initiative advocates

the inclusion of women in AI decision-making processes and promotes the development of AI systems that are free from gender biases. UNESCO has also partnered with governments and NGOs to implement gender-responsive AI education programs in regions where the digital divide is most severe.

4.2 Impact on Marginalized Communities

The impact of AI on marginalized communities extends beyond gender. In many parts of the world, indigenous populations, people with disabilities, and other marginalized groups face systemic barriers to accessing AI education and technology. For example, indigenous students are often excluded from mainstream educational systems that fail to accommodate their cultural and linguistic needs. As AI tools become more integrated into education, there is a risk that these communities could be further marginalized if their unique needs are not addressed.

UNESCO's "Inclusive Policy Lab" has been instrumental in advocating for policies that ensure that AI technologies are inclusive and accessible to all. This initiative emphasizes the importance of culturally responsive AI systems that respect the rights and identities of marginalized communities. Through collaborative efforts with local governments and organizations, UNESCO aims to create AI education programs that are tailored to the specific needs of these groups (UNESCO, 2024d).

Data from UNESCO's Global Education Monitoring (GEM) Report highlight the urgent need to address these disparities. The report shows that in low-income countries, only 17% of schools have access to the internet, whereas 90% of high-income countries do. This stark contrast underscores the digital divide that continues to widen the gap in AI education. Moreover, in regions where access to AI education is limited, students from marginalized communities are less likely to develop the skills needed to participate in the AI economy (UNESCO, 2023f).

To bridge this gap, UNESCO recommends targeted investments in infrastructure, teacher training, and culturally relevant curriculum development. These efforts are essential for ensuring that AI education is accessible to all individuals, regardless of their gender, socioeconomic status, or geographic location (UNESCO, 2023e, 2023f).

While AI has the potential to further develop education, its implementation is not without challenges. The EDUCAUSE Horizon Report 2024 warns of issues such as data privacy breaches, algorithm biases, and the weakening of traditional teacher–student relationships (Educase, 2024; UNESCO, 2024b). These challenges could impede the effective integration of AI in higher education, potentially widening the digital divide and increasing concerns about academic fairness. Addressing these challenges requires robust policy responses, including the development of transparent, inclusive, and equitable AI systems that prioritize the rights and dignity of all learners.

5. Conclusion and future perspectives

Artificial intelligence (AI) holds immense potential to transform education, offering opportunities to enhance the quality and accessibility of learning in alignment with Sustainable Development Goal 4 (SDG 4). However, the successful integration of AI

in education requires careful management to prevent exacerbating existing inequalities. To maximize the positive impact of AI on education, UNESCO emphasizes several critical actions. First, there is a pressing need for targeted investments in digital infrastructure, particularly in low-income regions, to support the widespread adoption of AI tools in educational settings. Such investments are essential to bridging the digital divide and ensuring that all learners, regardless of their socioeconomic background, have access to AI-enhanced education. Promoting inclusive AI is also crucial. AI tools must be designed with inclusivity in mind, ensuring that they are accessible to all learners, including marginalized groups and those in underserved areas. This approach not only helps reduce disparities in educational access and outcomes but also fosters a more equitable learning environment. Moreover, teacher training is a critical component of AI integration. Educators must be equipped with the necessary skills and knowledge to utilize AI effectively in their teaching practices. UNESCO's teacher training programs play a pivotal role in this regard, providing educators with the tools they need to harness AI's potential to improve learning outcomes.

Finally, the ethical and legal development and deployment of AI in education must be a top priority. This involves ensuring that AI systems are transparent, fair, and aligned with human rights. As AI becomes more integrated into educational systems, maintaining a strong ethical framework is essential to safeguarding the rights and dignity of all learners.

As AI continues to evolve, its role in education must be carefully managed to maximize its benefits while mitigating risks. The integration of AI into educational and enterprise practices presents significant opportunities to advance SDG 4, enhance student employability, and promote sustainable development. Future research should explore the practical applications of AI in various educational contexts, with a focus on developing strategies that address the ethical, social, and economic challenges associated with AI integration.

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The authors declare no conflicts of interest, financial or non-financial, that could have influenced the outcome or interpretation of this study.

Ethical Approval:

This article does not contain any studies with human participants or animals performed by any of the authors. Therefore, no ethical approval was required.

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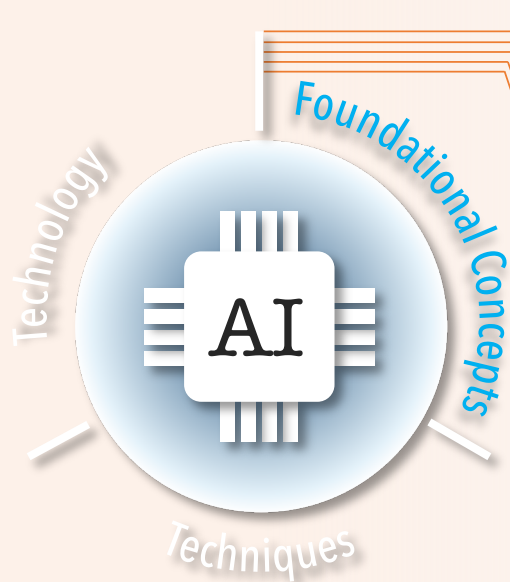
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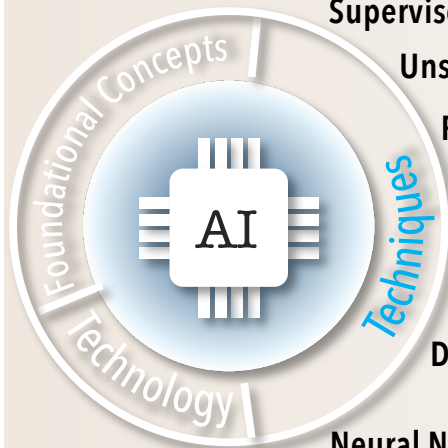
● FOUNDATIONAL CONCEPTS

- **Artificial Intelligence (AI):** AI involves machines designed to perform tasks typically requiring human intelligence, such as visual perception, speech recognition, and decision-making.
- **Machine Learning (ML):** ML is a subset of AI where algorithms learn patterns from data to make decisions without being explicitly programmed for each task.
- **Neural Networks (NN):** NNs are computational models inspired by the human brain, consisting of layers of interconnected nodes (neurons) that process data.
- **Deep Learning (DL):** DL is a subset of ML involving neural networks with many layers (deep neural networks), capable of learning from large amounts of data.
- **Large Language Models (LLM):** LLMs are deep learning models trained on vast amounts of text data, designed to understand, generate, and manipulate human language.

TECHNIQUES

FUNCTION

EXAMPLES



Supervised Learning: learns from labeled data to make prediction

Spam email detection, image classification

Unsupervised Learning: finds hidden patterns in unlabeled data

Customer segmentation, anomaly detection

Reinforcement Learning: learns by interacting with the environment, using rewards to reinforce desirable actions

Autonomous robotics, game playing (e.g., AlphaGo).

Generative Adversarial Networks (GANs):

two networks (generator and discriminator) work together to generate realistic data, such as images or audio

AI-generated art, synthetic data creation

Deep Learning (DL): extends NNs with multiple layers, enabling complex pattern recognition

Self-driving cars, facial recognition systems.

Neural Networks (NN): mimic the brain's structure to process data and identify patterns.

Handwriting recognition, speech processing

Natural Language Processing (NLP)

AI for interpreting and generating text, including semantic analysis and auto-journalism.

TEXT

AI Techniques: Machine Learning (ML), Deep Learning (DL), Regression, K-means

Otter,
Google BERT,
OpenAI GPT

Autonomous Agents

AI-powered agents like virtual companions, smart robots, and military drones.

AI Techniques: GOFAI (Good Old-Fashioned AI), DL, Reinforcement Learning

Woebot, Boston Dynamics' Spot



Speech Recognition

NLP applied to spoken words, used in personal assistants and conversational bots

AI Techniques: Deep Learning (Recurrent Neural Networks - LSTM)

Alibaba Cloud,
Google Assistant

Affect Detection

AI for analyzing sentiment in text, behavior, and faces..

AI Techniques: Bayesian Networks, Deep Learning

Affectiva, Microsoft
Azure Emotion API



PROUD...!

Image Recognition & Processing

AI for tasks like facial recognition, handwriting recognition, and autonomous vehicles.

AI Techniques: Deep Learning (Convolutional Neural Networks - CNN)

Google Lens,
Tesla Autopilot

Data Mining for Prediction

AI for predictions in areas like healthcare, weather forecasting, and fraud detection.

AI Techniques: Supervised Learning, Deep Learning, Support Vector Machines

IBM Watson Health, Google
DeepMind's AlphaFold

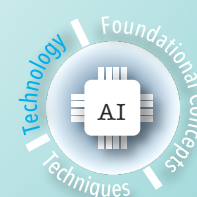


Artificial Creativity

AI systems that create new content like images, music, or stories.

AI Techniques: Generative Adversarial Networks (GANs), Autoregressive Models

OpenAI's DALL-E,
GPT-3, DeepArt



GLOBAL MEETING OF MINISTERS OF EDUCATION

Generative AI Guidelines

Teacher and Student
Competency Frameworks

Transparency

Curriculum
Development

Critical Thinking

Data Privacy

Interactive Learning

POLICY ADAPTATION



