United Nations
Educational, Scientific and
Cultural Organization

AI and education

Guidance for policy-makers

Education 2030

UNESCO Education Sector

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UNESCO
United Nations Educational, Scientific and Cultural Organization
Education Sector

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SHORT SUMMARY

AI and education: Promise and implications

Artificial Intelligence (AI) has the potential to address some of the biggest challenges in education today, innovate teaching and learning practices, and ultimately accelerate the progress towards SDG 4. However, these rapid technological developments inevitably bring multiple risks and challenges, which have so far outpaced policy debates and regulatory frameworks.

This publication offers guidance for policy-makers on how best to leverage the opportunities and address the risks, presented by the growing connection between AI and education.

AI in education is expected to be worth

$6 billion

by 2024

It starts with the essentials of AI: definitions, techniques and technologies. It continues with a detailed analysis of the emerging trends and implications of AI for teaching and learning, including how we can ensure the ethical, inclusive and equitable use of AI in education, how education can prepare humans to live and work with AI, and how AI can be applied to enhance education. It finally introduces the challenges of harnessing AI to achieve SDG 4 and offers concrete actionable recommendations for policy-makers to plan policies and programmes for local contexts.

UNESCO

'Since wars begin in the minds of men and women it is in the minds of men and women that the defences of peace must be constructed.'

Foreword

The rapid development of Artificial Intelligence (AI) is having a major impact on education. Advances in AI-powered solutions carry enormous potential for social good and the achievement of the Sustainable Development Goals. Making this happen requires system-wide policy adjustments and calls for robust ethical oversight as well as in-depth engagement with practitioners and researchers globally.

Policy-makers and educators have entered uncharted territory that raises fundamental questions on how the future of learning will interact with AI. The bottom line is that the deployment and use of AI in education must be guided by the core principles of inclusion and equity. For this to happen, policies must promote equitable and inclusive access to AI and the use of AI as a public good, with focus on empowering girls and women and disadvantaged socio-economic groups. The growing use of novel AI technologies in education will only benefit all of humanity if – by design – it enhances human-centred approaches to pedagogy, and respects ethical norms and standards. AI should be geared to improving learning for every student, empowering teachers and strengthening learning management systems. Beyond this, preparing students and all citizens to live and work safely and effectively with AI is a shared challenge at global level. Future learning and training systems must equip all people with core AI competencies, including understanding of how AI collects and can manipulate data, and skills to ensure safety and protection of personal data. Finally, AI by nature transcends the sectors, the planning of effective AI and education policies requires consultation and collaboration with stakeholders across disciplines and sectors.

UNESCO has been playing a lead role in fostering dialogue and knowledge in all these areas with key public and private sector players. A number of events and publications have raised awareness of the extensive opportunities and implications of AI for education, and helped Member States begin to respond to complex challenges. In 2019, the relationship between AI and sustainable development was explored at 'Mobile Learning Week', the United Nations' flagship event on Information and Communication Technology in education.

The same year, in cooperation with the Government of the People's Republic of China, UNESCO organized the 'International Conference on Artificial Intelligence and Education' in Beijing under the theme 'Planning Education in the AI Era: Lead the Leap'. This conference examined the system-wide impacts of AI on education, and it was here that the Beijing Consensus was adopted and released as the first-ever document to offer recommendations on how best to harness AI technologies for SDG4-Education 2030. The Beijing Consensus notably recommends that UNESCO develop guidelines and resources to support the capacity-building of education policy-makers and the integration of AI skills into ICT competency frameworks. More broadly, it calls on UNESCO to take a holistic approach to strengthening international cooperation in the field of AI and education with relevant partners.

'AI and education: Guidance for policy-makers' is developed within the framework of the implementation of the Beijing Consensus, aimed at fostering AI-ready policy-makers in education. It adds to the growing body of UNESCO's intellectual work in the field, and will be of interest to a range of practitioners and professionals in the policymaking and education communities. It aims to generate a shared understanding of the opportunities offered by AI for education, as well as its implications for the essential competencies required by the AI era. It presents a benefit-risk assessment to provoke critical thinking on how AI should be leveraged to address the challenges of reaching the SDG 4 targets, and how potential risks should be uncovered and mitigated. It collects emerging national policies and best practices on leveraging AI to enhance education and learning. This publication can also be used as a guidebook for the development of policies for AI and education, from planning a humanistic and strategic objectives, to setting out key building policy components and implementation strategies.

It is therefore my hope that the key policy questions, analysis of lessons learned, and the humanistic policy approach shared herein will help governments and partners to deploy AI in a way that transforms education and training systems for the common good of society, and for an inclusive and sustainable future.

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Assistant Director-General for Education
UNESCO

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AI and education
Guidance for policy-makers

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List of acronyms and abbreviations

AI	Artificial Intelligence
AI TA	AI Teaching Assistant
ANN	Artificial Neural Network
AR	Augmented Reality
AWE	Automated Writing Evaluation
CNN	Convolutional Neural Network
DBTS	Dialogue-Based Tutoring System
DigComp	European Digital Competence Framework
DNN	Deep Neural Networks
EEG	Electroencephalography
ELE	Exploratory Learning Environment
EMIS	Education Management Information System
GAN	Generative Adversarial Network
GDPR	General Data Protection Regulation
GOFAI	Good-Old-Fashioned AI
ICT	Information and Communication Technology
ILO	International Labour Organization
ITS	Intelligent Tutoring Systems
IoT	Internet of Things
LMS	Learning Management System
LNO	Learning Network Orchestrator
LSTM	Long Short-Term Memory
ML	Machine Learning
NLP	Natural Language Processing
OER	Open Educational Resources
RNN	Recurrent Neural Network
SDG	Sustainable Development Goal
STEM	Science, Technology, Engineering, and Mathematics
TVET	Technical and Vocational Education and Training
UNESCO	United Nations Educational, Scientific, and Cultural Organization
VR	Virtual Reality

1. Introduction

Within just the last five years, because of some prominent successes and its disruptive potential, artificial intelligence (AI) has moved from the backwaters of academic research to the forefront of public discussions, including those at the level of the United Nations. In many countries, AI has become pervasive in daily life – from smartphone personal assistants to customer support chatbots, from recommending entertainment to predicting crime, and from facial recognition to medical diagnoses.

However, while AI might have the potential to support the achievement of the Sustainable Development Goals (SDGs) of the United Nations, the rapid technological developments inevitably bring multiple risks and challenges, which have so far outpaced policy debates and regulatory frameworks. And, while the main worries might involve AI overpowering human agency, more imminent concerns involve AI's social and ethical implications – such as the misuse of personal data and the possibility that AI might actually exacerbate rather than reduce existing inequalities.

Nonetheless, AI has also entered the world of education. 'Intelligent', 'adaptive' and 'personalized' learning systems are increasingly being developed by the private sector for deployment in schools and universities around the world, creating a market expected to be worth US$6 billion in 2024 (Bhutani and Wadhwani, 2018). Inescapably, the application of AI in educational contexts raises profound questions – for example about what should be taught and how, the evolving role of teachers, and AI's social and ethical implications. There are also numerous challenges, including issues such as educational equity and access. There is also an emerging consensus that the very foundations of teaching and learning may be reshaped by the deployment of AI in education.

All of these issues are further complicated by the massive shift to online learning due to the COVID-19 school closures.

Accordingly, this UNESCO guidance seeks to help policy-makers better understand the possibilities and implications of AI for teaching and learning, so that its application in educational contexts genuinely helps achieve SDG 4: *Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*.

However, we must also be aware that the connection between AI and education will inevitably play out in very different ways depending on the national and socio-economic circumstances.

With AI in general, the concern is that

> **if we continue blindly forward, we should expect to see increased inequality alongside economic disruption, social unrest, and in some cases, political instability, with the technologically disadvantaged and underrepresented faring the worst. (Smith and Neupane, 2018, p. 12)**

This is no less a concern for AI and education. If AI is to support SDG 4, there is also a need to provide low-cost models for developing AI technologies, ensure that the interests of low and middle income countries are represented in key debates and decisions, and create bridges between these nations and countries where the implementation of AI is more advanced. This publication begins with a brief introduction to AI – what it is and how it works – to provide a foundation for an in-depth discussion of the interaction between AI and education. This is followed by an introduction to the multiple ways in which AI is being used in education, together with a discussion about how AI might enhance inclusion and equity, quality of learning, education management, and pedagogy. This discussion also considers how education might help all citizens develop the skills needed for life and work in the AI era. The main strategic objectives – harnessing the benefits and mitigating the risks of AI for education – are then detailed, and the challenges for achieving those objectives are explored. The guidance concludes by proposing a set of recommendations, which are designed to inform a comprehensive vision and action plans for AI-and-education policies.

2. AI essentials for policy-makers

2.1 The interdisciplinary nature of AI

The term 'artificial intelligence' was first used at a 1956 workshop held at Dartmouth College, a US Ivy League university, to describe the "science and engineering of making intelligent machines, especially intelligent computer programs" (McCarthy et al., 2006, p. 2)[1]. Over the following decades, AI developed in fits and starts, with periods of rapid progress interspersed with AI winters (Russell and Norvig, 2016).

All the while, definitions of AI multiplied and expanded, often becoming entangled with the philosophical questions of what constitutes 'intelligence' and whether machines can ever really be 'intelligent'. To give just one example, Zhong defined AI as

> **a branch of modern science and technology aiming at the exploration of the secrets of human intelligence on one hand and the transplantation of human intelligence to machines as much as possible on the other hand, so that machines would be able to perform functions as intelligently as they can. (Zhong, 2006, p. 90)**

Pragmatically sidestepping this long-running debate, for the purpose of this publication AI might be defined as computer systems that have been designed to interact with the world through capabilities that we usually think of as human (Luckin et al., 2016). More detail is given by UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), who describe AI as involving

> **machines capable of imitating certain functionalities of human intelligence, including such features as perception, learning, reasoning, problem solving, language interaction, and even producing creative work. (COMEST, 2019)**

Currently, we are experiencing an AI renaissance, with an ever-increasing range of sectors adopting the type of AI known as machine learning, which involves the AI system analysing huge amounts of data. This has come about as a result of two critical developments: the exponential growth of data (IBM has calculated that, due to the Internet and related technologies, more than 2.5 quintillion[2] bytes of data are created every day) and the exponential growth of computer processing power (because of Moore's law, today's mobile phones are as powerful as supercomputers were 40 years ago). Big data and powerful computers have both been essential to the successes of machine learning because its algorithms depend on the processing of millions of data points which, in turn, requires enormous amounts of computer power.[3]

Interestingly, the machine learning algorithms that are generating the most headlines – 'deep learning' and 'neural networks' – have themselves been around for more than 40 years. The recent dramatic achievements of AI and its disruptive potential have come about because of

TABLE 1: AI-AS-A-SERVICE EXAMPLES

TECHNOLOGY COMPANY	'AI AS A SERVICE' PLATFORM	COMPANY'S DESCRIPTION
Alibaba	Cloud	Cloud-based AI tools to support the demands of businesses, websites, or applications: https://www.alibabacloud.com
Amazon	AWS	Pre-trained AI service for computer vision, language, recommendations, and forecasting. It can quickly build, train and deploy machine learning models at scale or build custom models with support for all the popular open-source frameworks: https://aws.amazon.com/machine-learning
Baidu	EasyDL	Supports customers to build high-quality customized AI models without having to code: https://ai.baidu.com/easydl
Google	TensorFlow	An end-to-end open-source platform for machine learning, including an ecosystem of tools, libraries and community resources that enables researchers to share the state-of-the-art in machine learning and developers to easily build and deploy machine-learning-powered applications: https://www.tensorflow.org
IBM	Watson	Allows users to bring AI tools and apps to the data wherever it resides regardless of the host platform: https://www.ibm.com/watson
Microsoft	Azure	Includes more than 100 services to build, deploy and manage applications: https://azure.microsoft.com
Tencent	WeStart	Maps AI capabilities, professional talent and industry resources to support the launch or enhancements of start-ups. It connects industry partners, disseminates and applies AI technology in different industry sectors: https://westart.tencent.com/ai

Almost all of the world's big technology companies, and many others, now offer sophisticated 'AI-as-a-service' platforms, some of which are open-source. These provide various AI building-blocks that the developers can implement without having to write AI algorithms from scratch.

sophisticated refinements of these algorithms, together with their easy availability 'as a service', rather than because of any fundamental new paradigm. In other words, it might be argued that currently we are in the 'age of implementation':

> **Much of the difficult but abstract work of AI research has been done… the age of implementation means we will finally see real-world applications. (Lee, 2018, p. 13)**

Real-world applications of AI are becoming increasingly pervasive and disruptive, with well-known examples ranging from automatic translation between languages and automatic facial recognition, used for identifying travellers and tracking criminals, to self-driving vehicles and personal assistants on smartphones and other devices in our daily life. One particularly noteworthy area is health care. A recent transformative example is the application of AI to develop a novel drug capable of killing many species of antibiotic-resistant bacteria (Trafton, 2020). A second example is the application of AI to analyse medical imaging – including foetal brain scans to give an early indication of abnormalities,[4] retinal scans to diagnose diabetes,[5] and x-rays to improve tumour detection.[6] Together, these examples illustrate the potentially significant benefits of AI and humans working in symbiosis:

> **When we combine AI-based imaging technologies together with radiologists, what we have found is that the combination of the AI technology and the radiologist outperforms either the AI or the radiologist by themselves. (Michael Brady, Professor of Oncology, University of Oxford, quoted in *MIT Technology Review and GE Healthcare,* 2019)**

This recent review further suggested that the application of AI technologies may actually be 're-humanizing' health care:

> **The growth of AI and automated processes often creates concerns that the human touch will be removed from the health-care delivery process. What the industry is finding, however, is [that] the opposite is becoming true: AI can extend the resources and capabilities of overworked health-care professionals and vastly improve processes. (*MIT Technology Review and GE Healthcare,* 2019)**

Other increasingly common applications of AI include:

- **Auto-journalism**
  AI agents continually monitoring global news outlets and extracting key information for journalists, and also automatically writing some simple stories;
- **AI legal services**
  For example, providing automatic discovery tools, researching case law and statutes, and performing legal due diligence;
- **AI weather forecasting**
  Mining and automatically analysing vast amounts of historical meteorological data, in order to make predictions;
- **AI fraud detection**
  Automatically monitoring credit card usage, to identify patterns and anomalies (i.e. potentially fraudulent transactions);
- **AI-driven business processes**
  For example, autonomous manufacturing, market analysis, stock trading, and portfolio management;
- **Smart cities**
  Using AI and the interconnected Internet of Things (IoT) to improve efficiency and sustainability for people living and working in urban settings; and
- **AI robots**
  Physical machines that use AI techniques, such as machine vision and reinforcement learning, to help them interact with the world.

While each of these examples have significant positive potential for society, we should not neglect to point out that other applications of AI are more controversial. Two examples are:

- **Autonomous warfare**
  Weapons, drones and other military equipment that function without human intervention; and
- **Deep-fakes**
  Automatic generation of fake news, and the replacement of faces in videos so that politicians and celebrities appear to say or do things they never said or did.

In addition, we should also be careful when evaluating many of the dramatic claims made by some AI companies and the media. To begin with, despite headlines announcing that AI tools are now 'better' than humans at tasks such as reading texts and identifying objects in images, the reality is that these successes are only true in limited circumstances – for example, when the text is short and contains enough required information for inference to be unnecessary. Current AI technologies can also be very brittle. If the data is subtly altered, for example, if some random noise is superimposed on an image, the AI tool can fail badly (Marcus and Davis, 2019).[7]

2.2 A brief introduction to AI techniques

Each application of AI depends on a range of complex techniques, which require AI engineers to be trained in higher-level mathematics, statistics and other data sciences, as well as coding. Therefore, these techniques are too specialized to explore in depth here.[8] Instead, we will briefly introduce some core AI techniques, followed by some typical AI technologies.

Classical AI

Much early or 'classical AI', variously known as 'symbolic AI', 'rule-based AI', or 'good-old-fashioned AI' ('GOFAI'), involves writing sequences of IF... THEN... and other rules of conditional logic, steps that the computer will take to complete a task. Over decades, rule-based AI 'expert systems' were developed for a diverse range of applications, such as medical diagnostics, credit ratings, and manufacturing. Expert systems are based on an approach known as 'knowledge engineering', which involves eliciting and modelling the knowledge of experts in a specific domain, a resource-intensive task that is not without complications. Typical expert systems contain many hundreds of rules, yet it is usually possible to follow their logic. However, as the interactions between the rules multiply, expert systems can become challenging to revise or enhance.

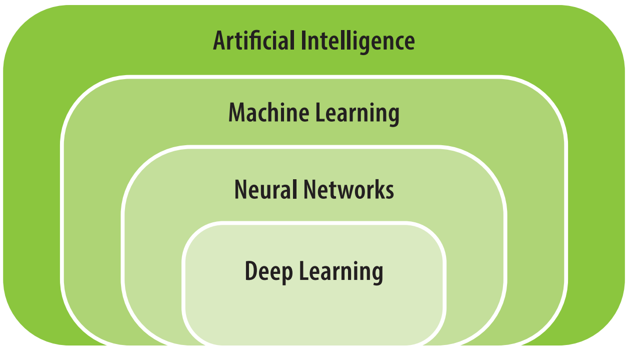
Machine learning

Many recent AI advances – including natural language processing, facial recognition, and self-driving cars – have been made possible by advances in machine-learning-based computational approaches. Rather than using rules, machine learning (ML) analyses large amounts of data to identify patterns and build a model which is then used to predict future values. It is in this sense that the algorithms, rather than being pre-programmed, are said to be 'learning'.

There are three main ML approaches: supervised, unsupervised, and reinforcement. Supervised learning involves data that has already been labelled – such as many thousands of photographs of people that have been labelled by humans. The supervised learning links the data to the labels, to build a model that can be applied to similar data – for example, to automatically identify people in new photographs. In unsupervised learning, the AI is provided with even larger amounts of data, but this time the data has not been categorized or labelled. The unsupervised learning aims to uncover hidden patterns in the data, clusters that can be used to classify new data. For example, it may automatically identify letters and numbers in handwriting by looking for patterns in thousands of examples.

In both supervised and unsupervised learning, the model derived from the data is fixed, and if the data changes, the analysis has to be undertaken again. However, the third ML approach, reinforcement learning, involves continuously improving the model based on feedback – in other words, this is machine learning in the sense that the learning is ongoing. The AI is provided with some initial data from which it derives a model, which is assessed as correct or incorrect and rewarded or punished accordingly. The AI uses this reinforcement to update its model and then it tries again, thus developing iteratively (learning and evolving) over time. For example, if an autonomous car avoids a collision, the model that enabled it to do so is rewarded (reinforced), enhancing its ability to avoid collisions in the future.

FIGURE 1: THE RELATIONSHIP BETWEEN ARTIFICIAL INTELLIGENCE, MACHINE LEARNING, NEURAL NETWORKS AND DEEP LEARNING.



ML is so widespread today that it is sometimes thought to be synonymous with AI, whereas it is actually a subset of AI. In fact, there are still many AI applications that do not use ML, or at least there is almost always some GOFAI (rule-based or symbolic AI) in the background. For example, many common chatbot applications are pre-programmed with human-defined rules about how to reply to anticipated questions. In fact, like the earlier expert systems,

> **Almost every AI product that you see today needs content inserted directly by human experts. This may be expertise harvested from linguists and phoneticians if the AI is using natural language processing, from physicians in cases where the AI is used in medicine, or perhaps even from experts in road traffic and driving when the AI powers self-driving cars, and so on. Machine learning could not create a full AI without the assistance of GOFAI components. (Säuberlich and Nikolić, 2018)**

Furthermore, it is important to recognize that ML does not really learn in the sense that a human learns. Nor does it learn independently. Instead, ML is entirely dependent on humans: they choose, clean, and label the data; design and train the AI algorithm; and curate, interpret, and make value judgements about the outputs. For example, a breakthrough object-recognition tool was said to identify pictures of cats in a database of images, but actually the system only grouped together objects that looked somehow similar, and it required a human to identify one set of those objects as cats. Similarly, the ML used in autonomous vehicles depends entirely on millions of images of street scenes being labelled by humans. To a large extent, Silicon Valley has outsourced this labelling to people around the world (using systems like Amazon Mechanical Turk)[9] and to companies in countries such as India, Kenya, Philippines and Ukraine.[10] The job of these new-economy workers is to trace by hand and label each object (such as vehicles, road signs, and pedestrians) in each frame of video captured by prototype autonomous vehicles – data that the ML algorithm then analyses.

Artificial neural networks

An artificial neural network (ANN) is an AI approach that is inspired by the structure of biological neural networks (i.e. animal brains). ANNs each comprise three types of interconnected layers of artificial neurons: an input layer, one or more hidden intermediary computational layers, and an output layer that delivers the result. During the ML process, weightings given to the connections between the neurons are adjusted in a process of reinforcement learning and 'back propagation', which allows the ANN to compute outputs for new data. A well-known example that uses an ANN is Google's AlphaGo, which in 2016 defeated the world's leading player of the game Go.

The hidden layers are the key to the power of ANNs, but they also bring an important constraint. It is usually not possible to interrogate a deep neural network to determine how it arrived at its solution. This leads to decision-making for which the rationale is unknowable. Many companies are researching ways in which such decisions can be opened up for inspection (Burt, 2019), so that users might understand why a given algorithm reached a particular decision – which is especially important when ANNs and other ML techniques are being used to make decisions that impact significantly on humans, such as how much time someone should remain in prison. However, as usual, this again complicates matters: "generating more information about AI decisions might create real benefits, [but] it may also create new risks" (Burt, 2019).

Deep learning

Deep learning refers to ANNs that comprise multiple intermediary layers. It is this approach that has led to many of the recent remarkable applications of AI (for example, in natural language processing, speech recognition, computer vision, image creation, drug discovery, and genomics). Emerging models in deep learning include so-called 'deep neural networks' (DNN), which find effective mathematical operations to turn an input into the required output; 'recurrent neural networks' (RNN), which allow data to flow in any direction, can process sequences of inputs, and are used for applications such as language modelling; and 'convolutional neural networks' (CNN), which process data that come in the form of multiple arrays, such as using three two-dimensional images to enable three-dimensional computer vision.

Finally, it is worth noting that many recent advances, especially those centred on image manipulation, have been achieved by what are called 'generative adversarial networks' (GANs). In a GAN, two deep neural networks compete against each other – one 'generative network' that creates possible outputs and one 'discriminative network' that evaluates those outputs. The outcome informs the next iteration. For example, DeepMind's AlphaZero used a GAN approach to learn how to play and win a number of board games (Dong et al., 2017). Meanwhile, a GAN trained on photographs has generated images of people who look real but do not exist.[11] Other applications of this approach are currently being studied.

2.3 A brief introduction to AI technologies

Together, all of the AI techniques described above have led to a range of AI technologies, which are increasingly being offered 'as a service' (see Table 1), and are being used in most of the aforementioned applications. AI technologies, which are detailed in Table 2, include the following:

- **Natural language processing (NLP)**
The use of AI to automatically interpret texts, including semantic analysis (as used in legal services and translation), and generate texts (as in auto-journalism).

- **Speech recognition:**
The application of NLP to spoken words, including smartphones, AI personal assistants, and conversational bots in banking services.

- **Image recognition and processing**
The use of AI for facial recognition (e.g. for electronic passports); handwriting recognition (e.g. for automated postal sorting); image manipulation (e.g. for deep-fakes); and autonomous vehicles.

- **Autonomous agents**
The use of AI in computer game avatars, malicious software bots, virtual companions, smart robots, and autonomous warfare.

- **Affect detection**
The use of AI to analyse sentiment in text, behaviour and faces.

- **Data mining for prediction**
The use of AI for medical diagnoses, weather forecasting, business projections, smart cities, financial predictions, and fraud detection.

- **Artificial creativity**
The use of AI in systems that can create new photographs, music, artwork, or stories.

TABLE 2: AI TECHNOLOGIES

TECHNOLOGY	DETAILS	MAIN AI TECHNIQUES	DEVELOPMENT	EXAMPLES
Natural language processing (NLP)	AI to automatically generate texts (as in auto-journalism), and interpret texts, including semantic analysis (as used in legal services and translation).	Machine learning (especially deep learning), regression, and K-means.	NLP, speech recognition, and image recognition have all achieved accuracy in excess of 90%. However, some researchers argue that, even with more data and faster processors, this will not be much improved until a new AI paradigm is developed.	Otter[12]
Speech recognition	NLP applied to spoken words, including smartphones, personal assistants, and conversational bots in banking services.	Machine learning, especially a deep learning recurrent neural network approach called long short-term memory (LSTM).		Alibaba Cloud[13]
Image recognition and processing	Includes facial recognition (e.g. for e-passports); handwriting recognition (e.g. for automated postal sorting); image manipulation (e.g. for deep-fakes); and autonomous vehicles.	Machine learning, especially deep learning convolutional neural networks.		Google Lens[14]
Autonomous agents	Includes computer game avatars, malicious software bots, virtual companions, smart robots, and autonomous warfare.	GOFAI and machine learning (for example, deep learning self-organizing neural networks, evolutionary learning and reinforcement learning).	Research efforts are focusing on emergent intelligence, coordinated activity, situatedness, and physical embodiment, inspired by simpler forms of biological life.	Woebot[15]
Affect detection	Includes text, behaviour and facial sentiment analyses.	Bayesian networks and machine learning, especially deep learning.	Multiple products are being developed globally; however, their use is often controversial.	Affectiva[16]
Data mining for prediction	Includes financial predictions, fraud detection, medical diagnoses, weather forecasting, business processes and smart cities.	Machine learning (especially supervised and deep learning), Bayes networks and support vector machines.	Data mining applications are growing exponentially, from predicting shopping purchases to interpreting noisy electroencephalography (EEG) signals.	Research project[17]
Artificial creativity	Includes systems that can create new photographs, music, artwork, or stories.	Generative adversarial networks (GANs), a type of deep learning involving two neural networks pitted against each other. Autoregressive language models that use deep learning to produce human-like text.	GANs are at the cutting edge of AI, such that future applications are only slowly becoming evident. An autoregressive language model known as GPT-3 can produce impressive human-like text. However, despite appearances, the system does not understand the text that it outputs.[18]	This Person Does Not Exist[11] GPT-3 (Brown et al., 2020)

2.4 Possible trends in AI developments: 'Weak' and 'strong' AI

While AI scientists started out with dreams of human-level artificial general intelligence (AGI), known as strong AI, each of the applications in section 2.1 are in fact examples of narrow or weak AI (Searle, 1980). The domain in which each narrow application operates is tightly constrained and limited, and the AI cannot be directly applied elsewhere. For example, the AI used to predict the weather is incapable of predicting movements in the stock market, while the AI used to drive a car is incapable of diagnosing a tumour. Nonetheless, although not 'intelligent' in a human sense, each of these applications can often outperform humans in efficiency and endurance, and by its ability to identify significant patterns in huge amounts of data.

Although there have been some notable successes, it is important to recognize that AI is still in its infancy. For example, it is impossible to have a real conversation with one of the personal assistants on our smartphones or other AI-powered household devices – instead, the AI responds only, and often inaccurately, to specific commands. In other words, while its performance of some functions (such as finding patterns in data) is superior to that of human experts, in others (such as holding an in-depth conversation), AI performs below the level of a two-year-old child.[19] In addition, there are signs from across the world that, contrary to the hyperbolic predictions, investment in AI technologies might be cooling – not yet another AI winter, but AI's promised potential all too often remains tantalisingly beyond the horizon (Lucas, 2018). It has even been suggested that progress in AI is soon to plateau (Marcus and Davis, 2019). For example, autonomous vehicles safely navigating the streets of Palermo or Delhi remain some decades away, while image-recognition apps are still easily fooled (Mitchell, 2019).

2.5 A critical view of the capabilities and limitations of AI

It may be useful to consider AI in terms of three basic types of achievement:

- AI technologies that represent "genuine, rapid technological progress", which mainly centre on 'perception' (including medical diagnosis from scans, speech to text, and deep-fakes) (Narayanan, 2019);
- AI technologies that are "far from perfect, but improving", which mainly centre on automating judgements (including the detection of spam and hate speech, and the recommendation of content) (*ibid.*); and
- AI technologies that are "fundamentally dubious", which mainly centre on predicting social outcomes (including criminal recidivism and job performance) (*ibid.*).

The key point is that, although deep neural networks have been trained to complete some incredible tasks, there are many things that they cannot do (Marcus and Davis, 2019). In particular, they are not doing anything that is genuinely intelligent. Instead,

> **they merely induce patterns through statistics. Those patterns may be opaquer, more mediated and more automatic than historical approaches and capable of representing more complex statistical phenomena, but they are still merely mathematical incarnations, not intelligent entities, no matter how spectacular their results. (Leetaru, 2018)**

Furthermore, various studies have shown that ML techniques that involve thousands of data variables or features, and therefore require large amounts of resources and energy to compute, can be little better than a simple linear regression that uses only a few features and much less energy (Narayanan, 2019).

Nonetheless, what does distinguish today's AI from previous technological revolutions is the speed at which it has developed, leading to novel technologies and transformative approaches emerging almost every day, and its pervasiveness, impacting on almost every aspect of modern life. To give just one impressive example, researchers have developed an AI system using a trio of deep-learning networks that outperforms human experts in breast cancer prediction (McKinney et al., 2020).

In any case, there is some evidence that in many contexts the successes of ML have been slightly exaggerated, and that the rapid improvements we have seen are possibly hitting a ceiling. For example, despite some extraordinary achievements, claims that ML is now as accurate as humans in identifying objects in pictures have two key limitations: they depend on (i) the system having access to millions of labelled images, whereas a young child only needs a few such images to reach the same level of accuracy; and (ii) a loose interpretation of accuracy (in one of the most publicized machine-vision competitions, an AI tool is deemed successful if just one of its five suggestions is correct) (Mitchell, 2019). In addition, as noted earlier, all of the techniques that are currently fuelling the major advances in AI (such as deep neural networks and ML) were first developed several decades ago. In other words, while we continue to see iterative refinements of existing techniques and new applications, we are still waiting for the next big breakthrough.

Some experts argue that this will only happen when the symbolic or rule-based techniques of so-called classical AI or GOFAI are combined with the data-driven techniques. This already happens in, for example, autonomous vehicles:

> **There are things that intelligent agents need to do that deep learning is not currently very good at. It's not very good at abstract inference. It's also not very good at handling situations it hasn't seen before and where it has relatively incomplete information. We therefore need to supplement deep learning with other tools… In my view, we need to bring together symbol manipulation (i.e. rule-based AI) with deep learning. They have been treated separately for too long. (Marcus interviewed by Ford, 2018, p. 318)**

2.6 Human-machine collaborative intelligence

AI was borne of attempts to simulate and mechanize human thought processes (Turing, 1950), and has existed in an uneasy relationship with them ever since. Interestingly, while we are used to reading about dramatic AI successes (ranging from defeating humans in games to reading retinal scans more accurately than humans), the limitations of current AI approaches are becoming increasingly clear (Mitchell, 2019). In fact, while AI has been good at processes that can be challenging for humans (such as pattern discovery and statistical reasoning), it remains weak at other processes that are relatively easy for humans (such as self-directed learning, common sense, and value judgements). This is known as Moravec's paradox:

> **It is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility. (Moravec, 1988, p. 15)**

In addition, as we have noted, the critical importance of humans to AI successes is often glossed over. Most of the time, humans are required to frame the problem; formulate the questions; select, clean and label the data; design or choose the algorithms; decide how the pieces fit together; draw conclusions and make judgments according to values;

and much more besides. Accordingly, although many tasks are likely to be automatable, there are still key roles for humans to play, for which we need to be properly prepared (Holmes et al., 2019).

In fact, the increasingly complex and nuanced relationship between humans and AI has led to calls for AI to be re-configured and re-branded as 'augmented intelligence' (Zheng, 2017).

For example, while computers can now easily beat humans at chess, computers and humans working together appear to be stronger than either working alone. In competitions, amateur chess players using AI have been able to beat computers and grandmasters alike (Brynjolfsson and McAfee, 2014). This approach involves using AI to enhance, rather than usurp, human capabilities. Shifting to *augmented* intelligence leads to an emphasis on developing AI technologies that complement and expand human cognition, suggests ways that humans and AI might work together more effectively, queries how tasks should be divided between humans and machines, and raises the tantalizing possibility that the world's problems might be addressed by means of a judicious mix of artificial and collective intelligence (Mulgan, 2018).

2.7 The Fourth Industrial Revolution and impact of AI on employment

AI is said to be a key enabler of the Fourth Industrial Revolution (Industry 4.0):

> **Of the many diverse and fascinating challenges we face today, the most intense and important is how to understand and shape the new technology revolution, which entails nothing less than a transformation of humankind.**
> **(Schwab, 2017, p. 1)**

Industry 4.0 technologies include 3D printing, autonomous vehicles, biotechnology, nanotechnology, quantum computing, robotics, and the Internet of Things, all of which are underpinned by AI. In fact, AI is already ubiquitous in the modern workplace – from manufacturing to banking, construction to transport, and beyond – which has implications that require a system-wide response. Inevitably, there will be increases in both unemployment and new occupations. A recent global estimate suggests that 30% of work activities could be automated by 2030. Up to 375 million workers worldwide could be affected. Both blue-collar workers and white-collar employees will be impacted, and it is not necessarily the former who will bear the brunt:

> **The jobs that AI can easily replicate and replace are those that require recently evolved skills like logic and algebra. They tend to be middle-income jobs. Conversely, the jobs that AI cannot easily replicate are those that rely on the deeply evolved skills like mobility and perception. They tend to be lower-income jobs. Hence, AI is hollowing out middle-income jobs and maintaining lots of lower-income jobs.**
> **(Joshi, 2017 © Courtesy of Guardian News & Media Ltd)**

Meanwhile, however, AI and other frontier technologies are increasing the range of high-skill jobs that require unique creative and analytical abilities and human interactions. In short, many workers' jobs might disappear, and they will need to develop new skill sets – upskilling or reskilling – to enable them to enter the new occupations made possible by AI. Education ministries and training providers need to anticipate these changes, equipping today's workers and preparing new generations with the necessary technical and social job skills, to smooth the transition to a world dominated by AI, while ensuring social sustainability.

In fact, many national agencies across the world have begun to develop strategic plans to address the future of AI. For example, in the United States of America, the National Artificial Intelligence Research and Development Strategic Plan (National Science and Technology Council, 2016) promotes long-term investment and research in a range of theoretical and practical AI approaches. These include data analytics, AI perception, theoretical limitations, artificial general intelligence, scalable AI, AI-driven humanoid robotics, human-aware AI, and human augmentation. In 2017, the Chinese Government announced its Next Generation of Artificial Intelligence Development Plan (Government of the People's Republic of China, 2017). Again, this focused on an array of theoretical and practical AI approaches, including big-data-based intelligence, cross-media intelligence, human-machine hybrid augmented intelligence, collective intelligence, autonomous intelligence, advanced machine learning, brain-inspired intelligence, and quantum intelligence. Most importantly, both plans emphasize the potential of seamless interactions between humans and AI systems, and both aim to help realize AI's potential social and economic benefits while minimizing the negative impacts.

3. Understanding AI and education: Emerging practices and benefit-risk assessment

The introduction of AI into educational contexts may be traced to the 1970s. At that time, researchers were interested in seeing how computers might substitute for one-to-one human tutoring, which is thought to be the most effective approach to teaching but is unavailable to most people (Bloom, 1984). Early efforts used rule-based AI techniques to automatically adapt or personalize the learning to each individual learner (Carbonell, 1970; Self, 1974). Since those beginnings, the application of AI in education has developed in multiple directions, beginning with student-facing AI (tools designed to support learning and assessment) to also include teacher-facing AI (designed to support teaching) and system-facing AI (designed to support the management of educational institutions) (Baker et al., 2019). In fact, the interaction between AI and education goes further, beyond the *application* of AI within classrooms (i.e. learning *with* AI) to teaching its techniques (i.e. learning *about* AI) and preparing citizens to live in the AI era (i.e. learning *for* human-AI collaboration). The introduction of AI into education also shines a spotlight on issues of pedagogy, organizational structures, access, ethics, equity, and sustainability – in order to automate something, you first need to thoroughly understand it.

Furthermore, if the potential of AI to support education for sustainable development is to be fully realized, all of the possible benefits of the tools need to be identified and leveraged, and the risks acknowledged and mitigated. As a consequence, the ways in which education is organized also need to be continuously reviewed, which might suggest a fundamental reshaping of education's core foundations, towards the central aim of addressing SDG 4. We also need to question what the introduction of AI into education might achieve: What are the real benefits AI might bring? How do we ensure that AI meets real needs, and is not just the latest EdTech fad? What should we allow AI to do?

To fully unleash the opportunities and mitigate the potential risks, system-wide responses to the following key policy questions are needed:

1. How can AI be leveraged to enhance education?
2. How can we ensure the ethical, inclusive and equitable use of AI in education?
3. How can education prepare humans to live and work with AI?

To help education systems respond to these complex challenges, UNESCO, in cooperation with the Chinese Government, organized the International Conference on Artificial Intelligence and Education in Beijing (2019) under the theme 'Planning Education in the AI Era: Lead the Leap'. Its participants included more than 50 government ministers and vice-ministers, and around 500 international representatives from more than 100 Member States, United Nations agencies, academic institutions, civil society and private sector organizations. They examined the system-wide impacts of AI in the context of 'SDG 4 – Education 2030 and the Future of Education Beyond 2030'. The key outcome of the conference was the 'Beijing Consensus on AI and Education' (UNESCO, 2019a) which provides a common understanding of key issues and policy recommendations relating to the three aforementioned policy questions. The main recommendations made in the Beijing Consensus are referenced throughout this publication.

The remainder of this chapter will review the main trends and issues affecting AI in education, as well as the benefit-risk dichotomy and implications for policy responses.

3.1 How can AI be leveraged to enhance education?

Over the past decade, the use of AI tools to support or enhance learning has grown exponentially (Holmes et al., 2019). This has only increased following the COVID-19 school closures. However, evidence remains scarce on how AI can improve learning outcomes and whether it can help learning scientists and practitioners to better understand how effective learning happens (Zawacki-Richter et al., 2019).

> **Many of the claims of the revolutionary potential of AI in education are based on conjecture, speculation, and optimism. (Nemorin, 2021)**

Furthermore, we have yet to explore AI's potential in the tracking of learning outcomes across different settings as well as assessing competencies, especially those acquired in non-formal and informal contexts.

AI applications designed for education have elsewhere been divided into three main categories: system-facing, student-facing and teacher-facing (Baker et al., 2019). However, for policy-makers, we propose a set of four needs-based categories of emerging and potential applications: (i) education management and delivery; (ii) learning and assessment; (iii) empowering teachers and enhancing teaching; and (iv) lifelong learning. For each of these categories, we also provide some illustrative cases. It is important to acknowledge that each of the proposed categories are intrinsically interlinked; applications of AI in education may have the potential to address needs in more than one area. For example, tutorial applications are may designed with the aim of supporting both teachers and students. It is also proposed that planning and policies for the adoption of AI technologies in educational contexts should be based on immediate and long-term local needs, rather than the market, and should be grounded in benefit-risk analyses before any of the technologies are adopted at scale. In particular, while proponents have suggested that AI provides a ready solution to the issues caused by the COVID-19 school closures and the shift to online learning, there is currently little evidence that such an approach is appropriate or effective.

The use of AI for education management and delivery

AI technologies are increasingly being used to facilitate the management and delivery of education. Rather than supporting teaching or learning directly, these system-facing applications are designed to automate aspects of school administration, building on Education Management Information Systems (Villanueva, 2003), and including admissions, timetabling, attendance and homework monitoring, and school inspections. Sometimes a data-mining approach known as 'learning analytics' (du Boulay et al., 2018) is used to analyse the big data generated in learning management systems to provide information for teachers and administrators, and sometimes guidance for students. For example, some learning analytics predict which students are at risk of failure. Outputs often take the form of visual 'dashboards' (Verbert et al., 2013), and are used to inform data-driven decision making (James et al., 2008; Marsh et al., 2006). Big data drawn from educational systems might also contribute to policy-making for delivery:

> **Public educational institutions increasingly utilize big data for creating digital and interactive data visualizations that can then give up-to-date information on the education system for policy-makers. (Giest, 2017, p. 377)**

For example, the data outputs of learning management systems established for refugees might help determine the optimal delivery of educational opportunities and support. AI has also demonstrated its potential to curate learning content across platforms based on analyses of learners' personalized needs and level of study. For example, one project aims to curate the many thousands of open educational resources, making them more easily accessible to all learners (Kreitmayer et al., 2018).

However, for any data-based analytics to be useful, with conclusions that are trustworthy and equitable, the original data and its proxies must be accurate and free from biases and poor assumptions, while the applied computational approaches must be both appropriate and robust – simple requirements that all too often are not rigorously met (Holmes et al., 2019). In any case, there are examples of AI companies collecting huge amounts of student interaction data just in order to use machine-learning techniques to 'search for patterns'. The aim is to improve student learning by teaching the software to identify when children are confused or bored, in order to help them become engaged. Nonetheless, this approach is controversial, with this kind of data collection being characterized as "borderline mental-health assessments..., [that] encourage a view of children as potential patients in need of treatment" (Herold, 2018).

In some contexts, AI tools under this category have also been used for monitoring student attention in class (Connor, 2018), while others have been used to track attendance (Harwell, 2019) and predict teachers' performance, with worrying consequences (O'Neil, 2017). These aspects of system-facing applications should be part of the wider discussion about AI and education.

Promising examples

- Educational chatbots: Chatbots are online computer programs that use cloud-based services and AI techniques to hold simulated conversations with people. The human user types or speaks a question, and the chatbot responds, providing information or undertaking a simple task. There are two levels of chatbot sophistication. While most chatbots use rules and keywords to select from pre-programmed scripted responses, virtual-assistant chatbots (such as Siri,[20] Alexa,[21] DuerOS,[22] and Xiaoyi)[23] use natural language processing and machine learning to generate unique responses. In educational contexts, chatbots are being used in an ever-growing range of applications. This includes facilitating student admissions (e.g. "What computing courses do you have?"); providing 24/7 information (e.g. "When is my assignment due?"); and directly supporting learning (perhaps as part of a dialogue-based tutoring system or DBTS approach (see page 16), engaging the student in a spoken dialogue or providing automated feedback). Educational chatbots include Ada[24] and Deakin Genie.[25]

- OU Analyse,[26] an AI application designed by the United Kingdom's Open University, has been designed to predict

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10. Be cognizant of the breakthrough in the use of data in transforming evidence-based policy planning processes. Consider integrating or developing AI technologies and tools that are relevant for upgrading education management information systems (EMIS) in order to enhance data collection and processing, making education management and provision more equitable, inclusive, open and personalized.

11. Consider also introducing new models for delivering education and training in different learning institutions and settings that can be enabled by the use of AI, in order to serve different actors such as students, teaching staff, parents and communities.

(UNESCO, 2019a, p. 5)

student outcomes and identify students at risk of failing by analysing big data from the university's education management information system (EMIS). The predictions are available to the course tutors and support teams, using easy-to-access dashboards, so that they might consider the most appropriate support. The overall objective is to enable students who might be having difficulties to complete their courses (Herodotou et al., 2017).

- 'Swift' is a set of methods developed by Swift eLearning Services in India to help EMIS systems leverage the data generated in an e-learning module.[27] The data collected from learner interactions provide valuable insight into when and why the learner might be struggling or achieving. Analysing this data helps create personalized learning pathways tailored to meet learner preferences.

- In the US, the ALP[28] system provides back-end AI functionality to support standard educational technologies. The system analyses user data, aggregating it to create psychometric profiles of each individual student's interactions, preferences, and achievements.

- Based in the US, but involving organizations from four continents, the UniTime[29] project is a comprehensive AI-powered educational scheduling system that develops timetables for university courses and examinations, manages time and room changes, and provides students' individual schedules.

The use of AI for learning and assessment

The use of AI technologies that are mostly student-facing, have received the most attention from researchers, developers, educators and policy-makers. These applications, which have been heralded as constituting a 'fourth education revolution' (Seldon and Abidoye, 2018), aim to provide every learner, wherever they are in the world, with access to high-quality, personalized, and ubiquitous lifelong learning (formal, informal and non-formal). There is also potential for AI to facilitate new approaches to assessment, such as AI-enabled adaptive and continuous assessment (Luckin, 2017). However, it is important to acknowledge at the outset that the use of AI for learning and assessment also raises various concerns that are yet to be properly addressed. These include concerns about their approach to pedagogy, the lack of robust evidence for their efficacy and potential impact on teachers' roles, and broader ethical questions (Holmes et al., 2018b, 2019).

Intelligent tutoring systems

For several reasons, we begin the discussion of the use of AI for learning and assessment with a set of tools known as 'intelligent tutoring systems' (ITS). Of all educational AI applications, ITS have been researched the longest (more than 40 years). They are the most common applications of AI in education and have been experienced by more students than any other. Moreover, they have attracted the highest level of investment and interest from the world's leading technology companies, and they have been adopted in education systems around the world for use with millions of students.

Generally speaking, the way ITS work is by providing step-by-step tutorials, individualized for each student, through topics in structured subjects such as mathematics or physics. The system determines an optimal pathway through the learning materials and activities by drawing on expert knowledge about the subject and cognitive sciences, and by responding to individual students' misconceptions and successes. This approach is also sometimes implemented in learning management systems, such as Moodle[30] and Open edX,[31] and platforms such as Kahn Academy.[32]

As the student engages with the learning activities, the system uses knowledge tracing[33] and machine learning to automatically adjust the level of difficulty and provide hints or guidance according to the individual student's strengths and weaknesses, all of which aim to ensure that the student is able to learn the topic efficiently. Some ITSs also capture and analyse data about the student's affective state, including by monitoring their gaze to infer their level of attention.

However, although intuitively appealing, it is important to recognize that assumptions embodied in ITS, and their typical instructionist knowledge-transmission approach to teaching, ignore the possibilities of other approaches valued by the learning sciences, such as collaborative learning, guided discovery learning, and productive failure (Dean Jr. and Kuhn, 2007). In particular, the 'personalized learning' provided by ITS typically personalises only the pathways to prescribed content, rather than promoting student agency by personalising the learning outcomes and enabling the student to achieve their own personal ambitions. In addition, although some studies have shown that some ITSs designed by researchers compare well with whole-class teaching (e.g. du Boulay, 2016), and despite the fact that they have been bought into by many education systems around the world, there is actually limited robust evidence that commercial ITS are as effective as their developers claim (Holmes et al., 2018a).

The extensive use of ITS raises other problems as well. For example, they tend to reduce human contact among students and teachers. Also, in a typical ITS classroom, the teacher often spends a great deal of time at their desk in order to monitor the dashboard of student interactions. If they choose to move around the room, as they might in a non-ITS classroom, they lose their access to what the students are doing, making it a challenge to decide where to give personal attention. To address this conundrum, an ITS extension called Lumilo (Holstein et al., 2018) uses augmented-reality smart glasses to 'float' information above each student's head about their learning (e.g. misconceptions) or behaviour (e.g. inattention), giving the teacher in-depth and continuous information on which they can act. This is a captivating use of a clever AI technology, but one that has, it is worth noting, been designed to address a problem only triggered by another use of AI technology. It is also an approach that raises issues of human rights, especially the right to privacy.

Globally, there are more than 60 commercial ITS available today, including Alef,[34] ALEKS,[35] Byjus,[36] Mathia,[37] Qubena,[38] Riiid,[39] and Squirrel AI.[40] An approach known as Hi-Tech Hi-Touch, that aims to leverage the best of ITS and the best of teachers, is currently being tested by the Education Commission in schools in Vietnam.[41]

Dialogue-based tutoring systems

Dialogue-based tutoring systems (DBTS) use natural language processing and other AI techniques to simulate a spoken tutorial dialogue between human tutors and students as they work step-by-step through online tasks most often in computer science topics, but more recently in less structured domains. DBTS adopt a Socratic approach to tutoring, probing with AI-generated questions rather than providing instruction, to develop a conversation in which the students are guided towards discovering for themselves an appropriate solution for a problem. The aim is to encourage students to co-create explanations to reach an in-depth understanding of the topic rather than the shallow understanding that can result from some instructional ITS.

Currently, there are relatively few DBTS in use. Most exist within research projects. The most extensively tested one is AutoTutor (Graesser et al., 2001). Watson Tutor is a commercial system that has been developed by IBM and Pearson Education.[42]

Exploratory learning environments

An alternative to the step-by-step approaches of ITS and DBTS is provided by exploratory learning environments (ELEs). ELEs adopt a constructivist philosophy: rather than following a step-by-step sequence such as the 'knowledge transmission' model favoured by ITS, students are encouraged to actively construct their own knowledge by exploring the learning environment and making connections with their existing knowledge schema. The role of AI in ELEs is to minimize the cognitive overload that is often associated with exploratory learning by providing automated guidance and feedback, based on knowledge tracing and machine learning. This feedback addresses misconceptions and proposes alternative approaches, to support the student while they explore.

Broadly speaking, ELEs have yet to emerge from research laboratories. Examples include 'ECHOES' (Bernardini et al., 2014); 'Fractions Lab' (Rummel et al., 2016); and 'Betty's Brain' (Leelawong and Biswas, 2008).

Automated writing evaluation

Rather than involving students working on computers while receiving immediate adaptive support, automated writing evaluation (AWE) uses natural language processing and other AI techniques to provide automatic feedback on writing. Generally, there are two overlapping AWE approaches: formative AWE to enable a student to improve their writing before submitting it for assessment, and summative AWE to facilitate the automatic scoring of students' writing.

In fact, most AWE focuses on scoring over feedback; they have been designed principally to drive down assessment costs, and thus may be considered as a component of systems-facing applications. However, ever since they were introduced, summative AWE have been controversial (Feathers, 2019). For example, they have been criticized for giving students credit for surface features such as sentence length, even if the text does not make any sense – they can be 'fooled by gibberish'. The systems are also unable to assess creativity. Most worryingly, the algorithms underpinning AWE are sometimes biased, especially against minority students, possibly due to different uses of vocabulary and sentence structure. Summative AWE also does not address easy-to-access 'deep-fake' school and university assignments – essays that are written by AI technologies, through drawing on domain expertise while imitating the writing style of the individual student. These are likely to be very difficult to detect.[43] Finally, the use of AI to mark assignments also does not acknowledge the value of marking. Even though marking can be time-consuming and tedious, it can also be a teacher's best opportunity to understand their students' competencies.

However, some student-facing AWE prioritizes giving feedback that is designed to be actionable – to help the student improve their writing, and to promote higher-order processes such as self-regulated learning and metacognition.

AWE, both formative and summative, is currently being used in many educational contexts through programs such as WriteToLearn,[44] e-Rater,[45] and Turnitin.[46] A related approach, using AI to compare a novel student output with a large corpus of previous student output assessed by teachers, has been used to evaluate musical performances, for example with the program Smartmusic.[47]

AI-supported reading and language learning

Reading and language learning tools are increasingly using AI to augment their approach. For example, some use ITS-style pathway personalisation along with AI-driven speech recognition. Typically, speech recognition is used to compare students' production with sample recordings of native speakers, to provide automatic feedback to help the student improve their pronunciation. Other uses of automatic translation involve helping students read learning materials in other languages, and enabling students from different cultures to more easily interact with each other. Meanwhile, other systems detect and automatically analyse reading skills in order to give students individual feedback.

Reading and language learning AI applications include AI Teacher,[48] Amazing English,[49] Babbel,[50] and Duolingo.[51]

Smart robots

The use of AI-enabled or 'smart' robots in education is also being explored (Belpaeme, 2018), particularly in settings for children with learning disabilities or difficulties. For example, speech-enabled humanoid robots have been created for learners on the autism spectrum, providing predictable mechanical interactions rather than human ones, which can be confusing for such learners. The aim is to develop their communication and social skills (Dautenhahn et al., 2009). Another example is telepresence robots for students who are unable to attend school, perhaps because of an illness or a humanitarian or refugee crisis, to access the classroom.[52] A third example is the use of humanoid robots, such as Nao[53] or Pepper[54] in kindergarten classes in Singapore (Graham, 2018), to introduce young children to computer programming and other STEM subjects.

Teachable agents

It has long been known that one may learn a topic more deeply and with better retention by teaching it to others (Cohen et al., 1982). This effect has been exploited by various AI approaches. For example, in the ELE mentioned earlier, Betty's Brain, students are encouraged to teach a virtual fellow student called Betty about a river ecosystem. In another example from a Swedish research project, the student teaches a virtual agent the rules of an educational game based on mathematics (Pareto, 2009). A third example, from Switzerland, involves young children teaching handwriting to a humanoid robot,[55] an approach which has been shown to stimulate meta-cognition, empathy, and self-esteem (Hood et al., 2015).

Educational virtual and augmented reality

Virtual reality (VR) and augmented reality (AR) are two related innovations that have been applied in educational contexts, and that are frequently combined with machine learning and other AI techniques to enhance the user experience. VR has been used in the teaching of many subjects, across K-12 and beyond, including astronomy, biology, and geology. VR goggles provide an immersive experience that shuts out the physical world, enabling users to feel as if they have been transported into a range of real-world or imagined environments (such as the surface of Mars, the inside of a volcano, or a human womb in which a foetus is developing). Some VR innovations use AI techniques to control lifelike virtual avatars, enable voice control using natural language processing, or generate entire environments from a few starting images.

AR, on the other hand, overlays computer-generated images on the user's view of the real world (much like a fighter pilot's heads-up display). AR is the aforementioned approach used by Lumilo to float information about a student's ITS performance above their head. When a smartphone's camera is pointed at a particular QR code, an AR 3D human heart might be revealed that can be explored in detail. AR might also involve AI-powered image recognition and tracking. This is the technology that makes it possible, on some mobile phones and sites such as Instagram or Snapchat, to place rabbit ears or cat whiskers on images of people. Examples of VR and AR being used in education include Blippar,[56] EonReality,[57] Google Education,[58] NeoBear,[59] and VR Monkey.[60]

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13. Dynamically review and define teachers' roles and required competencies in the context of teacher policies, strengthen teacher-training institutions, and develop appropriate capacity-building programmes to prepare teachers to work effectively in AI-rich education settings.
14. Be cognizant of trends regarding the potential of AI to support learning and learning assessments, and review and adjust curricula to promote the in-depth integration of AI and transformation of learning methodologies. Consider applying available AI tools or developing innovative AI solutions, where the benefits of AI use clearly outweigh the risks, to facilitate well-defined learning tasks in different subject areas and supporting the development of AI tools for interdisciplinary skills and competencies.
16. Apply or develop AI tools to support adaptive learning processes; to leverage the potential of data to enable the evaluation of the multiple dimensions of students' competencies; and to support large-scale and remote assessment.

(UNESCO, 2019a, pp. 5-6)

Learning network orchestrators

Learning network orchestrators (LNOs) are tools that enable networks of students and teachers to engage in learning and organize learning activities. LNOs typically match participants based on their availability, subject domain, and expertise, and can facilitate coordination and cooperation. One example, 'Third Space Learning', connects pupils in the United Kingdom who are at risk of failing maths with mathematics tutors from other countries.[61] Another is 'Smart Learning Partner', which involves an AI-driven platform that enables students to choose and connect with a human tutor via their mobile phones, somewhat like a dating app, to receive one-to-one support.[62]

AI-enabled collaborative learning

Collaborative learning, where students work together to solve problems, is known to enhance learning outcomes (Luckin et al., 2017), but effective collaboration between learners can be difficult to achieve. AI may transform collaborative learning in various ways: a tool could help connect learners remotely; it could identify the students best suited for particular collaborative tasks and group them accordingly; or it could actively contribute to the group discussions, as a virtual agent. While no specific examples have been identified, it is currently an area of research interest (e.g. Cukurova et al., 2017).

The use of AI to empower teachers and enhance teaching

Despite its potential to empower teachers, the use of teacher-facing AI applications to augment and enhance teachers and teaching has to date received far less attention than student-facing AI, which by definition replaces the teacher. Currently, researchers and developers often design for teachers only at the end of the process, for example by adding in a dashboard to display ITS student data. However, this is slowly beginning to be addressed.

Many teacher-facing AI applications aim to help teachers reduce workloads by automating tasks such as assessment, plagiarism detection, administration and feedback. This, it is often argued, should free up time for teachers to invest in other tasks, such as providing more effective support to individual students. However, as the AI develops, it is possible that teachers will be relieved of so many more tasks that the perceived need for teachers will be reduced to next to nothing. While this might have some benefits in contexts where teachers are scarce, the aim of eliminating the need for human teachers reveals a fundamental misunderstanding of their essential social role in the learning process.

Nonetheless, it is widely agreed that as AI tools become more available in classroom, it is likely that teacher roles will change. What is not yet clear is how this will happen. However, we know that teachers will need to build new competencies to enable them to work effectively with AI, and undertake appropriate professional development to foster their human and social capabilities.

AI-driven discussion forum monitoring

AI technologies are being used to support online education, especially to help teachers or facilitators monitor asynchronous discussion forums. On these forums, students give responses to given tasks, ask their tutors about course materials, and engage in collaborative learning opportunities. This typically generates large numbers of posts, all of which must be moderated and addressed. AI might help in a number of ways: a tool might triage the forum posts and automatically respond to the simpler ones; aggregate posts that raise overlapping issues; or use sentiment analysis to identify posts that reveal negative or non-productive emotional states. Together, these techniques might also enable human tutors to be kept informed of student opinions and collective worries. An example, albeit with some ethical issues, was the AI assistant 'Jill Watson', which was developed at Georgia Tech in the United States of America to triage forum posts and answer questions where possible (such as "When do I have to submit my assignment?"), while referring other more complex posts to human teaching assistants. This AI assistant was based on IBM's Watson platform. It automatically responded to some student questions, and sent emails to students about assignments (Goel and Polepeddi, 2017). Although it was thought to be successful, the ethics were criticized because it tricked students into thinking that the AI assistant was a real person – by, for example, delaying its responses and using humour.

AI-human 'dual teacher' model

Although there are some notable exceptions, much AI in education has been designed – whether intentionally or not – to replace some teacher tasks, rather than to assist teachers to teach more effectively. Some schools in China's remote rural areas already use what is known as a 'dual teacher model'. In this approach, an expert teacher gives a lecture over a video link to students in a distant classroom, who receive additional guidance from a less-experienced local teacher (iResearch Global, 2019). A future possibility is that an AI teaching assistant could support one of these roles. The AI could help the human teacher with many tasks, including providing specialist expertise or professional development resources, collaborating with colleagues, both within and outside the particular setting, monitoring the students' performance, and tracking progress over time. What and how to teach the students would remain the responsibility and prerogative of the teacher. The AI tool's role would simply be to make the teacher's job easier and more collegiate. An example is the 'LeWaijiao AI classroom',[63] which is designed to support human teachers so that they may conduct all of the key tasks.

AI-powered teaching assistants

As mentioned, many technologies are designed with the aim of relieving teachers of time-consuming activities such as taking attendance, marking assignments and answering the same questions over and over again. However, in so doing they effectively 'take over' much of the teaching (some claim to deliver personalized learning activities 'better than' teachers), interfere with the teacher-student relationship, and can reduce teachers to a functional role. For example, one aim of automatic writing evaluation (AWE) is to relieve teachers of the burden of marking. However, as we have noted, while marking can be onerous, it is often a key opportunity for teachers to learn about their students' strategies and capabilities. This can be lost with the use of AWE.

In addition, this approach clearly undervalues teachers' unique skills and experiences, as well as learners' social and guidance needs. Instead of just automating computer-based teaching, AI might help open up teaching and learning possibilities that are otherwise difficult to achieve, or that challenge or even disrupt existing pedagogies. Such an approach would aim to augment a teacher's expertise, perhaps by means of an AI teaching assistant (AI TA) (Luckin and Holmes, 2017). There are some AI applications designed to empower teachers and schools to facilitate transformation in learning. Some research on these has been undertaken, but many technical and ethical issues need to be overcome before they can be harnessed in real settings.

3.2 How can AI be best exploited for the common good in education?

As has been explored, AI is already being used in educational contexts in multiple ways. However, despite using cutting-edge technologies, these applications often do little more than automate some outmoded classroom practices, rather than using the unique affordances of AI to reimagine teaching and learning. In other words, the attention of AI researchers and developers working in education has so far been focused on the relatively easy to address, although still complex, low-hanging fruit of memorising and recalling knowledge. Few possibilities that address more complex educational issues, such as collaborative learning or new ways to assess and accredit, have yet to be fully researched, let alone made available as commercial products at scale. Accordingly, here, in order to stimulate a dialogue, some innovative ways in which AI might be exploited for the common good in education are suggested.

AI-driven lifelong learning companions

The desire for every student to have their own personalized lifelong tutor is what first inspired the use of AI in learning. Technically speaking, it would not necessarily be difficult to leverage the capabilities of smartphones and related technologies to create an AI-driven learning companion that could accompany individual learners throughout their life. Rather than setting out to teach the student in the manner of an instructionist ITS, a learning companion would provide continuous support, building on the individual student's interests and goals, to help them decide what to learn, as well as where and how. It could also guide the student along individualized learning pathways designed to help them address their emerging goals and connect their learning interests and achievements, while encouraging them to reflect on and revise their long-term learning aims. However, despite the profound potential, there are currently no commercial AI-enabled lifelong learning products, and little research.

AI-enabled continuous assessment

Although there is little evidence for their validity, reliability or accuracy, high-stakes examinations are central in educational systems around the world. With such examinations in place, schools and universities often teach to the test, prioritizing routine cognitive skills and knowledge acquisition (the types of knowledge being supplanted by AI) over in-depth understanding and authentic application.

In fact, AI is already being developed to extend existing examination practices. For example, AI-driven face recognition, voice recognition, keyboard dynamics, and text forensics are increasingly being used to verify candidates in examinations for distance learners.[64] Although this might have benefits for some students (e.g. those with disabilities who find it challenging to attend face-to-face examinations), these tools have not proved effective at scale, and they perpetuate rather than ameliorate the problems of exam-based assessment practices.

An alternative approach to assessment might be possible with AI tools designed to constantly monitor student progress, to provide targeted feedback and assess the student's mastery. All of this information might be collated throughout a student's time in formal educational settings. While the use of AI-driven continuous assessment to replace high-stakes stop-and-test examinations may be attractive, it also illustrates the two sides of applying AI in education : the benefits and the challenges. Allowing students to demonstrate their competencies while they learn is advantageous in some respects, but how this might be achieved without continuous monitoring – i.e. surveillance – is less clear. Such monitoring involves many ethical concerns.

AI-enabled record of lifelong learning achievements

An 'AI-driven e-portfolio' might be used to collate all of the continuous assessment information, recorded throughout a student's time in formal education, together with data on the student's engagement with non-formal learning (such as learning a musical instrument or a craft) and informal learning (such as acquiring a language). This record would function as an intelligent and dynamic resumé that could be underwritten and authenticated by blockchain technologies.[65] In this way, students would have a robust, accredited record of their learning experiences and achievements, potentially far more detailed than a collection of exam certificates. They would be able to share secure access to relevant parts of their e-portfolio with higher education providers and prospective employers.

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20. Reaffirm that the guiding principle for achieving SDG 4 is lifelong learning, which encompasses formal, non-formal and informal learning. Adopt AI platforms and data-based learning analytics as key technologies in building integrated lifelong learning systems to enable personalized learning anytime, anywhere and potentially for anyone, with respect for learners' agency. Exploit the potential of AI to enable flexible learning pathways and the accumulation, recognition, certification and transfer of individual learning outcomes.

21. Be mindful of the need to give appropriate policy attention to the needs of older people, especially older women, and to engage them in developing the values and skills needed for living with AI in order to break the barriers to digital life. Plan and implement well-funded programmes to equip older workers with skills and options that enable them to remain economically active for as long as they choose and to engage in their societies.

(UNESCO, 2019a, p. 7)

3.3 How can we ensure the ethical, inclusive and equitable use of AI in education?

The ethical, inclusive and equitable use of AI in education impacts upon each of the Sustainable Development Goals. There are issues centred on data and algorithms, on pedagogical choices, on inclusion and the 'digital divide', on children's right to privacy, liberty and unhindered development, and on equity in terms of gender, disability, social and economic status, ethnic and cultural background, and geographic location.

Emerging ethical and legal issues relating to educational data and algorithms

The widespread deployment of AI technologies brings multiple risks and challenges, such as those centred on data ownership (e.g. the exploitation of data for commercial gain), consent (e.g. whether students are capable, either developmentally or legally, of giving genuinely informed consent), and privacy (e.g. the use of intrusive emotion-detection systems). Another risk is that algorithmic biases might undermine basic human rights. There is also the additional concern that AI data and expertise are being accumulated by a small number of international technology and military superpowers. Nonetheless, while the range of AI technologies in education is extensive and growing,

> **Around the world, virtually no research has been undertaken, no guidelines have been agreed, no policies have been developed, and no regulations have been enacted to address the specific ethical issues raised by the use of artificial intelligence in education. (Holmes et al., 2018b, p. 552)**

As with mainstream AI, concerns exist about the large volumes of personal data collected to support the application of AI in education – a process that has been called 'dataveillance' (Lupton and Williamson, 2017). Who owns and who is able to access this data, what are the privacy and confidentiality concerns, and how should the data be analysed, interpreted, and shared? All learners are susceptible to having their personal data misused or compromised, especially given that less than 30% of countries across the world (excluding Europe) have comprehensive data protection laws in place.

Another major concern is the potential for conscious or unconscious bias incorporated into AI algorithms (i.e. how the data is analysed).

In fact, algorithms are playing an increasingly widespread role in society, automating a wide range of tasks ranging from decisions that impact whether someone gets a job to how long someone should remain in prison. However, people are increasingly recognising that algorithms are not as neutral as they are often presented; and that, for example, they can automate biases with varying degrees of negative consequences for individuals (Hume, 2017).

Any biased analysis might impact negatively on the human rights of individual students (in terms of their gender, age, race, socio-economic status, income inequality, and so on). However, these particular ethical concerns, centred on data and bias, are the 'known unknowns' and are the subject of much discussion in mainstream AI.[66] But there are suggestions that leading technology companies' interest in 'ethics washing' is growing, in an attempt to avoid national or international regulation (Hao, 2019). We must also consider the 'unknown unknowns', those ethical issues raised by the interaction of AI and education that have yet to be identified. Ethical questions include:

- What criteria should be considered in defining and continuously updating the ethical boundaries of the collection and use of learners' data?
- How might schools, students, and teachers opt out from, or challenge, their representation in large datasets?
- What are the ethical implications of not being able to easily interrogate how AI makes decisions (using multi-level neural networks)?
- What are the ethical obligations of private organizations (product developers) and public authorities (schools and universities involved in research)?
- How does the transient nature of students' interests and emotions as well as the complexity of the learning process impact on the interpretation of data and ethics of AI applied in educational contexts?

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Ensuring ethical, transparent and auditable use of education data and algorithms:

28. Be cognizant that AI applications can impose different kinds of bias that are inherent in the data the technology is trained on and uses as input, as well as in the way that the processes and algorithms are constructed and used. Be cognizant of the dilemmas of balancing between open access to data and data privacy protection. Be mindful of the legal issues and ethical risks related to data ownership, data privacy and data availability for the public good. Be mindful of the importance of adopting principles of ethics-, privacy- and security-by-design.
29. Test and adopt emerging AI technologies and tools for ensuring teachers' and learners' data privacy protection and data security. Support robust and long-term study of deeper issues of ethics in AI, ensuring AI is used for good and preventing its harmful applications. Develop comprehensive data protection laws and regulatory frameworks to guarantee the ethical, non-discriminatory, equitable, transparent and auditable use and reuse of learners' data.
30. Adjust existing regulatory frameworks or adopt new ones to ensure responsible development and use of AI tools for education and learning. Facilitate research on issues related to AI ethics, data privacy and security, and on concerns about AI's negative impact on human rights and gender equality.

(UNESCO, 2019a, pp. 8-9)

- What pedagogical approaches are ethically warranted?

In addition, the application of AI in education has been criticised for being both intrusive and de-humanising: intrusive because some applications require continual monitoring of student actions, gestures and emotions; de-humanising because some AI requires students to fit into prescriptive methods of teaching, with minimal human interaction, following structured pathways of atomized content, which reduces learner agency. There are cases that have exposed ethical controversies, such as recording lessons and using AI to analyse how the quality of classroom talk contributes to learning (Kelly et al., 2018). The use of AI to identify learning patterns and problems is perhaps less ethically problematic if devices are not introduced to classrooms in an intrusive manner. However, in some schools AI-driven classroom cameras are used to monitor student behaviour (Loizos, 2017). This has crossed ethical boundaries because facial recognition technology is installed to check how attentive students are in class. Every movement of the students is watched by multiple cameras positioned above the blackboard. The system works by identifying facial expressions and feeding that information into a computer to assess whether the students are concentrating or if their minds are wandering. In one example, the computer targets seven different emotions: neutral, happy, sad, disappointed, angry, scared and surprised. If it concludes that the student is distracted, it will send a notification to the teacher to take action. However, these cameras have raised anxiety levels and changed students' natural behaviours. Students have reported that they feel like a pair of mystery eyes are constantly watching them.

Another AI-driven approach goes further still, by using electroencephalography (EEG)[67] sensors in headbands to detect brain activity when the student is engaged in a task. Again, the developers claim that this technology has the potential to improve learning – a claim that has been questioned by neuroscientists. These headbands might lead to inaccurate results or unintended consequences. Of note is that, in October 2019, China's Cyberspace Administration and Ministry of Education introduced regulations designed to curb the use of AI-powered cameras, headbands, and other devices in schools (Feng, 2019). These regulations require parental consent to be obtained before AI technologies are used with students. They also require all data to be encrypted. This has had the effect of halting, although possibly only temporarily, the use of facial recognition and EEG technologies in Chinese schools.

In the Beijing Consensus, the ethics of AI in education are articulated in paragraphs 28 to 30. The Consensus also recommends that all governments should develop and implement regulatory frameworks to ensure the responsible development and use of AI tools for education and learning. This should build on UNESCO's 'Recommendation on the Ethics of Artificial Intelligence' (2020), which is currently in development.

The divide between those with and without access to core digital technologies, such as the Internet and AI, is a concern that impacts upon each of the SDGs. To complicate matters, this digital divide exists in many dimensions, for example: between developed and developing countries, between different socio-economic groups within countries, between the owners and users of the technologies, and between those whose jobs are enhanced by AI and those whose jobs are susceptible to being replaced.

To focus briefly on one example, disparities in access to telecommunications networks affect many people in developing countries as well as people in rural settings in developed countries. In addition, although broadband prices have reduced significantly in recent years, digital services and devices remain unaffordable for many, creating a barrier to widespread AI uptake. In fact, poor broadband can lead to a vicious cycle: without broadband, there is limited access to digital technologies, and those without access do not appear in the data sets upon which machine learning depends. In this way, the hopes, interests, and values of those on the wrong side of the digital divide are excluded in the AI era, and new AI is unintentionally biased against them.

The digital divide is further exacerbated by the increasing concentration of power and profitability in a small number of international technology superpowers, across just a few countries. Without effective policy intervention, the deployment of AI in education is likely to mirror this inexorable process, inevitably magnifying rather than ameliorating existing learning inequalities.

Opportunities for AI to advance inclusion and equity in education

In addition to focusing on equitable access to AI technologies for all, we also need to consider the potential of AI to help achieve SDG 4, to help '*ensure inclusive and equitable quality education and promote lifelong learning opportunities for all*'. To achieve universal primary and secondary education by 2030, 68.8 million more teachers need to be recruited globally (UNESCO, 2016). In this challenging context, many AI technologies might be used, or further developed, to help improve education – especially for older people, refugees, marginalized or isolated communities, and people with special educational needs.[68] However, we must be cognisant that increasing access to education remains predominantly a political and social issue. AI technologies might help, but they are unlikely to offer a solution. For example, focusing on AI technologies that replace teacher functions, rather than those that augment teacher capabilities, might contribute toward a short-term fix for contexts where teachers are scarce, but might unintentionally exacerbate rather than address the long-term challenges in achieving SDG 4.

Accordingly, it is incumbent upon policy-makers to ensure that the currently hyped potential of AI to improve education and learning is considered critically. To begin with, the

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22. Reaffirm that ensuring inclusion and equity in and through education, and offering lifelong learning opportunities to all, are the cornerstones of achieving SDG 4 – Education 2030. Reaffirm that technological breakthroughs in the field of AI in education are an opportunity to improve access to education for the most vulnerable groups.

23. Ensure that AI promotes high-quality education and learning opportunities for all, irrespective of gender, disability, social or economic status, ethnic or cultural background, or geographic location. The development and use of AI in education should not deepen the digital divide and must not display bias against any minority or vulnerable groups.

24. Ensure that AI tools in teaching and learning enable the effective inclusion of students with learning impairments or disabilities and those studying in a language other than their mother tongue.

33. Monitor and assess the impact of the AI divide and disparities in AI development across countries based on data voluntarily submitted by countries, and be mindful of the risks of polarization between those who have access to AI and those who do not. Reiterate the importance of addressing these concerns, giving special priority to Africa, least developed countries (LDCs), small island developing states (SIDS) and countries affected by conflict and disaster.

34. Coordinate collective actions to promote the equitable use of AI in education in the context of the global and regional Education 2030 architecture, including through sharing AI technology, programmes and resources for capacity-building, with due respect for human rights and gender equality.

35. Support forward-looking reviews of frontier issues related to the implications of emerging AI development, and facilitate the exploration of effective strategies and practices for using AI to innovate in education, with an aim of building an international community with common views on AI and education.

36. Align international cooperation with national needs for the use of AI in education and for cross-sectoral cooperation, in order to enhance ownership of the development of AI technology among AI professionals. Strengthen the sharing of information and promising practices, as well as coordination and complementary actions among countries.

(UNESCO, 2019a, pp. 7 & 9)

UNESCO's ROAM framework ('Rights, Openness, Access and Multi-stakeholder Governance') should be applied, to ensure that the application of AI in education addresses broader human rights and emerging ethical issues in a holistic manner (UNESCO, 2019b). For example, and in particular, AI in education should be made accessible to all citizens (irrespective of gender, disability, social or economic status, ethnic or cultural background, or geographic location), especially for vulnerable groups (such as refugees or students with learning disabilities), without exacerbating existing inequalities.

There are various examples of AI being used to advance inclusion and equity in education:

- The Global Digital Library,[69] which uses Google Voice Assistant to enable people with literacy difficulties to search for books using only voice commands, and then to have the books read out loud to them, giving them access to knowledge;
- Dytective, an AI-powered screening tool using machine learning for the early detection of dyslexia. Developed by Change Dyslexia, a Spanish company, it also provides a game-based learning environment for practising 24 key literacy skills;[70]
- AI-powered artificial voices for people who are unable to speak or who have speech impediments,[71] sometimes designed to match the person's original voice.
- AI-powered automatic speech recognition and transcription to convert raw spoken language into fluent, punctuated text, and make live lectures more accessible for deaf and hard-of-hearing students;[72]
- AI and augmented reality applications to help deaf children read by translating texts into sign languages, such as StorySign,[73] a mobile app developed by Huawei;
- AI-enabled 'smart' robots, such as speech-enabled robots for learners on the autism spectrum,[74] that provide predictable mechanical interactions to help learners develop their communication and social skills;
- Telepresence robots for students who are unable to attend school (Heikkila, 2018); and
- AI-powered intelligent tutoring systems (ITS), the most common AI tools in education, some of which are used to diagnose specific learning difficulties and personalize learning pathways (ITS are discussed in section 3.1 on p. 15).

The complexity of ensuring the inclusive and equitable use of AI in education has been reflected in the Beijing Consensus. Guiding principles and strategies are recommended to steer AI towards inclusion and equity.

3.4 How can education prepare humans to live and work with AI?

As we noted earlier, computers are better at tasks that depend on data, pattern discovery, and statistical reasoning, while humans continue to be more accomplished at tasks that require empathy, self-direction, common sense, and value judgements. In other words, helping students learn how to live effectively in a world increasingly impacted by AI requires a pedagogy that, rather than focusing on what computers are good at (e.g. memorizing and computation), puts more emphasis on human skills (e.g. critical thinking, communication, collaboration and creativity) and the ability to collaborate with pervasive AI tools in life, learning, and work.

As noted earlier, the Fourth Industrial Revolution is impacting on many aspects of modern life, especially the labour market. In many countries, AI is already taking over standardized and repetitive work, revolutionizing efficiencies but displacing many jobs. Yet, according to some of the world's leading consultancies,[75] AI is also likely to create many new job opportunities and have an overall positive economic benefit, although they disagree about how many jobs will be supplanted and created.

Whatever the long-term outcomes, the very nature of employment is likely to change ("working life is impermanent and unpredictable", Barrett, 2017), with millions of workers being significantly and often negatively affected. Many will have to retrain; multiple careers in a lifetime is fast becoming the new normal.[76] At the same time, the skills gap[77] between those who can and cannot work with the new technologies will continue to grow, such that increasing numbers of workers will be excluded from the job market, and there will be a 'hollowing-out' of the middle classes (Smith and Anderson, 2014). The combination of opportunities and risks also requires collective work to determine how developments can benefit everybody. The recent ILO report, 'Work for a Brighter Future: Global Commission on the Future of Work' (ILO, 2019) states:

> **Countless opportunities lie ahead to improve the quality of working lives, expand choice, close the gender gap, [and] reverse the damages wreaked by global inequality. Yet none of this will happen by itself. Without decisive action we will be sleepwalking into a world that widens existing inequalities and uncertainties.**

In fact, if the world is to ensure that AI does not exacerbate existing inequalities, it will be increasingly important for every citizen to have the opportunity to develop a robust understanding of AI – what it is, how it works, and how it might impact on their lives. This is sometimes called 'AI literacy'. For this, teachers will play a key role, and educational provision will have to shift toward supporting lifelong learning so that people can build their agency, employability, and ability to contribute to society. In other words, education and training approaches worldwide will need to take a system-wide response to help prepare all citizens to live and work harmoniously in the AI era.

Mainstreaming the necessary human values and skills will require a system-wide, even a society-wide, framework involving several complementary dimensions:

(i) facilitating lifelong learning, so that everyone (especially older people) gains a robust understanding of AI[78] (in particular, how data are selected, manipulated by AI algorithms, and interpreted, and how this may be biased) and its implications for individuals and wider society;

(ii) integrating fundamental AI learning into K-12 school curricula[79] (including computational thinking, data and algorithm literacy, coding and statistics, to enable young people to generate their own AI tools), which we look at in more detail later;

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6. We also recognize the distinctive features of human intelligence. Recalling the principles set forth in the Universal Declaration of Human Rights, we reaffirm UNESCO's humanistic approach to the use of AI with a view towards protecting human rights and preparing all people with the appropriate values and skills needed for effective human–machine collaboration in life, learning and work.

17. Be mindful of the systemic and long-term transformation of the labour market, including its gender dynamics, due to AI adoption. Update and develop mechanisms and tools to identify current and future skills needs in relation to AI development, in order to ensure the relevance of curricula to changing economies, labour markets and societies. Integrate AI-related skills into the school curricula and qualifications of technical and vocational education and training (TVET) and higher education, taking into consideration the ethical aspects and interrelated humanistic disciplines.

18. Be cognizant of the emergence of a set of AI literacy skills required for effective human–machine collaboration, without losing sight of the need for foundational skills such as literacy and numeracy. Take institutional actions to enhance AI literacy across all layers of society.

19. Set up mid- or long-term plans and take urgent actions to support higher education and research institutions in developing or enhancing courses and research programmes to foster local AI talent, in order to create a pool of local professionals who have the expertise to design, programme and develop AI systems.

(UNESCO, 2019a, pp. 4 & 6)

(iii) training the next generation of AI professionals to address the growing skills gap and fill the AI jobs being created worldwide;

(iv) fostering higher education and research institutions to develop ground-breaking equitable AI;

(v) ensuring that the growing AI workforce is diverse and inclusive (involving women and other groups that are often excluded); and

(vi) anticipating the emerging needs of employees and employers and providing opportunities for on-the-job upskilling or reskilling (as AI automates low-skill and middle-skill functions).

There are various promising examples of programmes to prepare humans to live and work with AI, which include helping very young learners to build AI skills. Meanwhile, various AI platforms and tools are also being produced to support these skills:

- In China, 'algorithms and computational thinking' has been included in the Ministry of Education's 'ICT Curriculum Standards for Senior High School' (Ministry of Education, People's Republic of China, 2017), while the 'Innovative Action Plan for Artificial Intelligence in Higher Education Institutions' (Ministry of Education, People's Republic of China, 2018) aims to enhance the AI capability of China's universities. In addition the Ministry has released a pilot programme 'AI Boosts Teachers' Team Development' which aims to enhance innovation in teacher education.

- In the United States of America, the Montour School District in Pennsylvania teaches AI coding to children, providing students with opportunities to experience designing AI to increase the public good.[80]

- In Singapore, humanoid robots (such as Nao[53] and Pepper)[54] are being used in kindergarten classes to introduce children to programming and other STEM subjects (Graham, 2018).

- In the United Kingdom and Kenya, the Teens In AI initiative[81] aims to inspire the next generation of AI researchers, entrepreneurs and leaders. It gives young people exposure to socially-aware AI deployment, through a combination of hackathons, accelerators, bootcamps and mentoring.

- In Singapore, the SkillsFuture[82] initiative focuses on digital upskilling and reskilling. In particular, it provides skill sets for AI scientists and engineers and a foundational understanding of AI, including how to live well in an AI world.

- In Finland, an AI application called Headai was developed in association with Helsinki Metropolitan University of Applied Sciences. It monitors and analyses job advertisements and the university's curricula to create competency maps[83] that compare the demand and supply of AI skills, which in turn enables the university to quickly pivot its courses to address the needs of the market.

- The US AI4K12[84] initiative, jointly sponsored by the Association for the Advancement of Artificial Intelligence (AAAI) and the Computer Science Teachers Association (CSTA), provides a set of resources designed to help teachers introduce their students to AI.

- UNESCO's 'Teaching AI for K12'[85] portal, which brings together AI teaching resources from around the world for any teacher, or home-schooler, to use to help their students learn about AI.

- Free online courses have been designed to familiarize citizens with how AI works. These include:

  - Elements of AI:[86] a series of free online courses created by Reaktor and the University of Helsinki. The courses are available in several languages and aim to encourage people to learn what AI is, what it can and cannot do, and how to start creating AI methods.

  - OKAI:[87] a series of online courses available in English and Chinese. The project aims to demystify AI and introduce its concepts to an audience with limited or no background in computer science. It utilizes web-based interactive graphics and animations to illustrate the working principles of AI.

  - AI-4-All:[88] a US-based non-profit programme dedicated to increasing diversity and inclusion in AI education, research, development, and policy, with the aim of creating more access for under-represented people in the field of AI.

4. The challenges of harnessing AI to achieve SDG 4

Despite the potential of AI for education, there are many challenges specific to harnessing AI to achieve SDG 4. There are also broader obstacles that society must surmount to unleash the potential of AI and mitigate its downsides, and build future-proof education systems. To begin with, AI's impact on students, teachers and wider society is yet to be determined. This includes questions about the efficacy of AI interventions, the choice of pedagogies used in AI tools, students' privacy, teachers' jobs, and what we should be teaching at schools and universities. In this chapter, we briefly explore some of the key issues that still need to be addressed.

4.1 Data ethics and algorithmic biases

As has been discussed, data is at the heart of contemporary approaches to AI, which raises numerous challenging issues centred on data protection, privacy, and ownership, and on data analysis. These ethical issues have received a great deal of attention (summarized by Jobin et al., 2019). Similarly, the ethics of educational data has also been the focus of much research (e.g. Ferguson et al., 2016), raising further issues centred on informed consent, the management of data, and perspectives (e.g. institutional vs individual) on data. Any application of AI in educational contexts should properly address these many data issues, together with other issues specific to education, such as choice of pedagogy.

In addition, it has long been recognized that by design, AI amplifies hidden features of its initial data and effectively reinforces its underlying assumptions. In particular, if the algorithms

> **are trained on data which contains human bias then of course the algorithms will learn it, but furthermore they are likely to amplify it. This is a huge problem, especially if people assume that algorithms are impartial. (Douglas, 2017)**

In short, AI is not biased in itself. Instead, if its data are biased or analysed with inappropriate algorithms, the original and perhaps unidentified biases can become more noticeable and have a greater impact. Making the biases noticeable is probably helpful, because it can lead to corrections, but allowing the biases to have a greater impact can lead to prejudicial outcomes and so should be carefully mitigated.

4.2 Gender-equitable AI and AI for gender equality

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25. Underline that the gender gap in digital skills contributes to the low share of women among AI professionals and exacerbates existing gender inequalities.
26. Affirm our commitment to developing AI applications in education that are free from gender bias and ensuring that the data used for AI development are gender sensitive. AI applications should drive the promotion of gender equality.
27. Promote gender equality in the development of AI tools and empower girls and women with AI skills to promote gender equality among workforces and employers.

(UNESCO, 2019a, p. 8)

If AI is to be of genuine benefit to society, every effort must be taken to ensure that fairness and gender equality are among its fundamental principles. Yet, various uses of AI have been shown to be gender biased. For example, in 2018 the tech giant Amazon abandoned the use of machine learning in its recruitment because it was systematically discriminating against female candidates. The root cause was the fact that the original data, based on historical records of the company's recruitment, had always been unknowingly biased against women. The AI, in automating selection, inevitably amplified and made obvious those original prejudices. Some have suggested that Amazon should not have abandoned their use of AI in recruitment but instead should have worked to address the bias. Another example centres on the development of AI personal assistants, such as Apple's Siri,[20] Amazon's Alexa,[21] and Baidu's DuerOS.[22] Many of these tools are given female names and voices, leading to subtle but serious implications:

> **With their female names, voices and programmed flirtatiousness, the design of virtual personal assistants reproduces discriminatory stereotypes of female secretaries who, according to the gender stereotype, is often more than just a secretary to her male boss. It also reinforces the role of women as secondary and submissive to men. These AI assistants operate on the command of their user. They have no right to refuse these commands. They are programmed only to obey. Arguably, they also raise expectations for how real women ought to behave. (Adams, 2019)**

What the impact might be of using these gender-stereotyped technologies in classrooms is an open question.

Addressing these issues of gender equity is a critical goal that is only likely to be realized if women are adequately represented in the AI workforce, which is itself the subject of much disquiet. A recent LinkedIn analysis revealed that only 22% of AI professionals globally are female (World Economic Forum, 2018). Advancing women's representation in AI is essential for fundamental human rights and to help prevent the proliferation and amplification of AI-driven biases.

4.3 Monitoring, evaluation and research into the use of AI in education

Although the application of AI in education has been researched for more than 50 years, it is notable that it still remains relatively uncommon in schools and universities—even in developed countries. In fact, it is not even clear yet whether the technologies being imported into education are actually up to the task.

> **Much of what exists now as "evidence-based" is mostly related to how AI can work in education in a technical capacity without pausing to ask and comprehensively answer the question of whether AI is needed in education at all. (Nemorin, 2021)**

There are few examples of cumulative or replicable research on the application of AI in education, and little available robust evidence of its efficacy at scale, although some ITS have been shown to be broadly effective when compared against traditional classroom teaching (du Boulay, 2016). In fact, the purported efficacy of many AI tools may be due more to their novelty than their substance. We simply do not have sufficient evidence (Holmes et al., 2018a).

While there appears little doubt that AI will have a major impact on the delivery and management of educational opportunities, content and outcomes, we are still unsure about how AI solutions can improve those outcomes, and whether they can help scientists better understand how learning happens.

In particular, many have suggested that AI has a major role to play in addressing the educational problems, such as rising inequities, caused by the COVID-19 school closures. During the early months of the pandemic, many commercial AI in education companies reported large increases in registered users. However, there remains little evidence that these systems were being used for much more than virtual child-minding, or that young people gained much from engaging with them. Accordingly, before policy-makers assume that AI can solve the educational problems caused by the pandemic, much further research and evaluation is required to distinguish the reality from the hyperbole. Ultimately, AI is likely to be able to play a useful role, but at present we simply do not have enough information to know how helpful it will be.

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15. Support school-wide pilot tests on the use of AI to facilitate innovation in teaching and learning, drawing lessons from successful cases and scaling up evidence-based practices.

31. Be mindful of the lack of systematic studies on the impacts of AI applications in education. Support research, innovation and analysis on the effects of AI on learning practices and outcomes, and on the emergence and validation of new forms of learning. Take an interdisciplinary approach to research on AI in education. Encourage cross-national comparative research and collaboration.

32. Consider the development of monitoring and evaluation mechanisms to measure the impact of AI on education, teaching and learning, in order to provide a valid and robust evidence-based foundation for policy-making.

(UNESCO, 2019a, pp. 6 & 9)

4.4 What impact will AI have on teacher roles?

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12. Be mindful that while AI provides opportunities to support teachers in their educational and pedagogical responsibilities, human interaction and collaboration between teachers and learners must remain at the core of education. Be aware that teachers cannot be displaced by machines, and ensure that their rights and working conditions are protected.

13. Dynamically review and define teachers' roles and required competencies in the context of teacher policies, strengthen teacher training institutions, and develop appropriate capacity-building programmes to prepare teachers to work effectively in AI-rich education settings.

(UNESCO, 2019a, p. 5)

Despite the commercial aims of using intelligent tutorial systems to do teacher tasks, it is still unlikely that teachers will be replaced by machines any time soon. Nonetheless, the ambition of many AI developers is to relieve teachers of various burdens (such as monitoring progress and marking assignments), so that they may focus on the human aspects of teaching (such as social engagement, interacting with empathy, and offering personal guidance). However, as AI functionalities improve, they will inevitably relieve teachers of increasing numbers of burdens. Accordingly, as the AI tools take over the knowledge transmission tasks, facilitating students' lower-order thinking, teachers will play a reduced role. Theoretically, this will allow teachers to focus more on the design and facilitation of learning activities that require higher-order thinking, creativity, interpersonal collaboration, and social values – although, no doubt, AI developers are already working to automate these tasks too. Accordingly, to ensure that teachers continue their critical role in the education of young people policy-makers must review strategically how AI might transform teachers' roles, and how teachers might prepare to work in AI-rich education environments.

4.5 What impact will AI have on learner agency?

Even if the dystopian scenario of replacing teachers with AI is avoided, learners' agency might be undermined by more use of adaptive AI in education. This means less time for learners to interact with each other, more decisions made by machines, and more focus on the type of knowledge that is easiest to automate. This could deprive learners of opportunities to cultivate their resourcefulness, self-efficacy, self-regulation, metacognition, critical thinking, independent thought and other 21st century skills that are key to developing the whole person (World Economic Forum and Boston Consulting Group, 2016). It is currently unknown what long-term effects this will have on student, civic and educational formulations.

One ITS, Summit Learning, which was developed by engineers from Facebook and is being used in around 400 schools, has been the focus of student protests and boycotts. In more than one school, the students walked out in protest saying that they didn't have a good experience using the programme, which required hours of classroom time sitting in front of computers. They were especially concerned that the programme eliminated much of the human interaction and teacher support needed to develop critical thinking (Robinson and Hernandez, 2018). The Chan Zuckerberg Initiative, which funded the Summit Learning project, disputes these claims.

In addition, as already noted, AI amplifies hidden features of its initial data and effectively reinforces its underlying assumptions. In this respect, rule-based and machine-learning AI technologies are similar (Holmes et al., 2019). Their very design, their implementation of mostly instructionist methods that focus on knowledge transfer and content delivery while ignoring contextual and social factors, amplifies existing yet contested assumptions about approaches to teaching and learning. This is a critical set of issues with which the AI-in-education community needs to fully engage. All applications of AI in education should enhance, not threaten, what it means to be fully human.

5. A review of policy responses

As noted by the OECD,[89] there exists more than 300 AI policy initiatives from 60 countries all around the world, and from the EU. Most of these make some reference to education. For example, many refer to the need for AI capacity building (i.e. 'learning *about* AI'), although mostly in Higher Education. Some also mention the retraining that is becoming increasingly necessary to mitigate the impact of AI on workers.

However, despite SDG 4, few initiatives focus on learning about AI in K12 contexts, how AI is being implemented in education (i.e. 'learning *with* AI'), or preparing citizens to live in a world increasingly impacted on by AI (i.e. 'learning *for* human-AI collaboration').

In this chapter we summarize some national and regional polices that do specifically address AI and education, to inform the work of decision-makers in other countries as they develop strategies by building on existing generic AI initiatives.

5.1 Approaches to policy responses

Cross-national and regional policies addressing AI and education developments are diverse, but may be loosely categorized as adopting one of three approaches: independent, integrated or thematic (see Table 3).

- **Independent approach**
Having stand-alone AI policies and strategies, such as the EU's 'The Impact of Artificial Intelligence on Learning, Teaching, and Education' (Tuomi, 2018), and China's (2017) 'New-Generation Artificial Intelligence Development Plan'.

- **Integrated approach**
Integrating the elements of AI into existing Education or ICT policies and strategies, such as Argentina's 'Aprender Conectados' (Ministry of Education, Argentina, 2017).

- **Thematic approach**
Focusing on one specific topic relating to AI and education, such as the EU's General Data Protection Regulation (GDPR).

Each of these three approaches will now be explored in more detail.

Independent approach

- In 2016, the United States launched the 'National Artificial Intelligence Research and Development Strategic Plan'. With regard to AI in education, the plan emphasizes improving educational opportunities and quality of life. More specifically, it argues that (i) adaptive automated tutoring can become universally available, by means of AI-enhanced learning technologies; (ii) AI tutors can complement human teachers, helping to provide advanced and remedial learning appropriate to the individual; and (iii) AI tools can foster lifelong learning and the acquisition of new skills for all members of society.

- In 2016, the Republic of Korea launched the 'Mid- to Long-Term Plan in Preparation for the Intelligent Information Society'. This plan includes the training of 5,000 new AI graduates every year, beginning in 2020, to add 50,000 new AI specialists to its talent pool by 2030.

- In 2017, China launched the 'New-Generation Artificial Intelligence Development Plan'. It argues for what it calls 'intelligent education'. Specifically, the plan involves making use of AI to (i) develop a new education system that involves the reform of educational practices and delivers intelligent and interactive learning; (ii) carry out intelligent campus construction and promote AI in teaching, management and resource construction; (iii) develop a three-dimensional comprehensive teaching methodology and an intelligent online learning platform based on big data; (iv) develop AI assistants and establish a comprehensive educational analysis system; and (v) establish a learner-centred education environment, and achieve personalized education for every learner.

- In 2017, the United Arab Emirates (UAE) launched the 'UAE Strategy for Artificial Intelligence'. This plan covers the development and application of AI in nine main sectors, one of which is education. It emphasizes the potential of AI to reduce costs and enhance learning.

- In 2018, the EU released 'The Impact of Artificial Intelligence on Learning, Teaching, and Education', a document that firstly addresses the impact of AI on learning, especially on the human cognitive capacities of children and adults. It argues that AI can support existing cognitive skills, speed up cognitive development and create new capacities, and might reduce the importance of some capacities or make them obsolete. Secondly, it addresses the need for future-oriented vision regarding AI, and the impact of AI on the future of learning, especially on AI-generated student models and new pedagogical opportunities. Furthermore, this document emphasizes that AI is likely to have a profound impact on a systemic level. It acknowledges that AI is just one aspect of the ongoing broader transformations known as the Fourth Industrial Revolution. In order to cope in such a context, the authors argue that it is essential to rethink the role of education in society, how it might be organized, and what aims and needs it should address.

TABLE 3: OVERVIEW OF POLICY GUIDELINES ASSOCIATED WITH AI IN EDUCATION

	APPROACHES		
	Independent	Integrated	Thematic
Argentina		Aprender Conectados (Ministry of Education, Argentina, 2017)	
China	Next Generation Artificial Intelligence Plan (Government of the People's Republic of China, 2017).		New ICT Curriculum Standards for Senior High School (Ministry of Education, People's Republic of China, 2017) Innovative Action Plan for Artificial Intelligence in Higher Education Institutions (Ministry of Education, People's Republic of China, 2018)
Estonia			ProgeTiger Programme (HITSA, 2017)
European Union	The Impact of Artificial Intelligence on Learning, Teaching, and Education (Tuomi, 2018)		GDPR (European Union, 2016, 2018) DigComp (Carretero et al., 2017)
Malaysia		#mydigitalmaker (Ministry of Education & Malaysia Digital Economy Corporation, 2017)	
Malta	Towards an AI Strategy. High-level policy document for public consultation (Government of Malta, 2019)		
Republic of Korea	Mid- to Long-Term Plan in Preparation for the Intelligent Information Society (Government of the Republic of Korea, 2016)		
Singapore			Code@SG Movement-Developing Computational Thinking as a National Capability (Infocomm Media Development Authority, 2017)
United Arab Emirates	UAE Strategy for Artificial Intelligence (United Arab Emirates, 2017)		
United States of America	National Artificial Intelligence Research and Development Strategic Plan (National Science and Technology Council, 2016)		

- In 2019, Malta launched 'Towards an AI Strategy'. This is built on three strategic pillars: (i) investment, start-ups and innovation; (ii) public sector adoption; and (iii) private sector adoption, with education being a key enabler. It states that the country's education system must

> **Evolve and adapt to the requirements of the Fourth Industrial Revolution. A high percentage of young children today learn to expertly interact with electronic devices and navigate mobile operating systems, before they can speak. They grow up viewing technology as integral to their life. In fact, they are rarely sentimental about the idea of 'disconnecting', having never known a world without continuously streamed personalized content to an always-connected mobile device. As such, digital tools are commonplace across most of Malta's schools, with teachers augmenting the educational experience with interactive whiteboards and tablets. However… Malta must [also] consider how to expand the curriculum itself and better prepare children for a future workplace where decision making is assisted, supported and enhanced by the application of AI. (Government of Malta, 2019)**

Integrated approach

- In 2016, Malaysia launched the #mydigitalmaker movement, which integrates computational thinking in its educational programme. It proposes collaborations across the private sector, public sector and academia to 'help create and encourage the development of digital making curriculums that are mapped to the objectives set by the Ministry of Education' (Ministry of Education & Malaysia Digital Economy Corporation, 2017) (Pedro et al., 2019).

- In 2017, Argentina launched 'Aprender Conectados', which aims to integrate digital learning across all levels of compulsory education. It proposed that all schools should embed programming and robotics by 2019. The curriculum prescribes specific, age-appropriate learning competencies at each level, from pre-school to secondary school, building towards full competency in using computing methods and techniques, individually and collaboratively, to solve problems.

Thematic approach

- In 2016, the EU Parliament approved the 'General Data Protection Regulation' (GDPR), which came into force in 2018. It is designed to (i) harmonize data privacy laws across Europe; (ii) protect the data privacy of all EU citizens; and (iii) reshape the way organizations across Europe approach data privacy.

- In 2017, the EU launched the 'European Digital Competence Framework' ('DigComp') (Carretero et al., 2017), in which digital competence is understood to include (i) information and data literacy; (ii) communication and collaboration; (iii) digital content creation; (iv) safety; and (v) problem solving.

- In 2017, China launched the 'New ICT Curriculum Standards for Senior High School' (Ministry of Education, People's Republic of China, 2017). This document promotes students' (i) information consciousness; (ii) computational thinking; (iii) digital learning and innovation; and (iv) responsibilities in an information society.

According to the 'New ICT Curriculum Standards for Senior High School,' the ICT curriculum involves the ICT Compulsory Course, ICT Selective Course I, and ICT Selective Course II. The ICT Compulsory Course includes two modules: (i) Data and Calculation, (ii) Information System and Society. The ICT Selective Course consists of a basic module and an application module. The basic module includes (i) Data and data structures, (ii) Network basics, and (iii) Data Management and Analysis. The application module includes (i) APP Design, (ii) 3D Design and Creativity and (iii) Design for Open Hardware Project. The ICT Selective Course II involves Algorithm basics and Introduction to Intelligent Systems.

- In 2018, China launched the 'Innovative Action Plan for Artificial Intelligence in Higher Education Institutions' (Ministry of Education, People's Republic of China, 2018), which pushes forward AI development in universities. It aims to (i) optimize innovation system in the field of AI in college and universities; (ii) improve AI talent training system; and (iii) strengthen the application of the science and technology achievement of colleges and universities in the field of AI.

- In 2017, Singapore launched 'The Code@SG Movement - Developing Computational Thinking as a National Capability' (Infocomm Media Development Authority, 2017), which emphasizes the importance of promoting students' coding and computational thinking from an early age, as it becomes an increasingly essential part of people's lives and careers.

- In 2012, Estonia launched the 'ProgeTiger' Programme managed by the Education Information Technology Foundation (Hariduse Infotehnoloogia Sihtasutuse, HITSA), and funded by the Estonian Ministry of Education and Research. It proposes to introduce programming and robotics into the national curricula for pre-school, primary and vocational education.

5.2 Common areas of concern

From the national and regional policies described above, four main areas of concern emerge:

- the importance of governance for data and privacy (as addressed by, for example, the EU's GDPR);
- the importance of openness as a core value, in terms both of AI technologies and data, to ensure equal universal access and opportunities to bridge information inequalities and to promote transparency (UNESCO, 2019b);
- curriculum innovation that can address the potential and implications of AI, such as Malta's 'Towards an AI Strategy. High-level policy document for public consultation' (Government of Malta, 2018), which asserts that "Malta's education system will also need to evolve and adapt to the requirements of the Fourth Industrial Revolution"; and
- financial support for the effective implementation of AI, such as the Republic of Korea's creation of 4,500 domestic scholarships for AI students and its commitment of around US$2 billion to establish six new AI graduate institutions and $4 million for AI research.

5.3 Financing, partnership and international cooperation

To maximize the benefits and mitigate the risks of AI's growth in educational contexts, it is essential to have system-wide planning, critical evaluations, collective actions, sustained funding, robust targeted research and international cooperation. The reality is that few countries or stakeholders are ready. Few are genuinely engaging with the technologies or mobilizing resources to ensure that the application of AI is grounded in large-scale academic research. Most are yet to acknowledge let alone explore the fact that AI may demand a fundamental reinvention of learning. Instead, the discussion remains rather superficial. For example, many argue that 'personalisation' of learning is welcome, but this is ill-defined; do they mean personalized routes to learning standardised content, or personalized outcomes, agency and self-actualization? In short, it is not sufficient to argue that AI should be used in educational contexts. Instead, stakeholders must also consider which AI technologies should be used, how they should be used, and what they can genuinely achieve.

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37. Provide adequate platforms for the international exchange of regulatory frameworks, instruments and approaches to AI in education, including through UNESCO's Mobile Learning Week and through other United Nations agencies, and thereby support and benefit from South–South and North–South–South cooperation to leverage AI for SDG 4.
38. Create multi stakeholder partnerships and mobilize resources to reduce the AI divide and increase investment in the application of AI in education.

(UNESCO, 2019a, p. 10)

6. Policy recommendations

6.1 A system-wide vision and strategic priorities

DEFINE A SYSTEM-WIDE VISION OF AI AND EDUCATION POLICIES

The primary purpose of applying AI in education should be to enhance learning, enabling every learner to develop their individual potential, which policies should reflect and support. However, if countries are to meet the challenges of achieving SDG 4, policies need to go beyond the application of AI in educational contexts, to include all the connections between AI and education. In particular, this means teaching how AI works and how it might be created, and about the wider implications that AI has for local and global society.

Four strategic targets need to be met, interpreted for the local context (i.e. for many low and middle-income countries, the focus might need to be on identifying and addressing gaps in AI readiness such as those around infrastructure and funding):

- Ensuring the inclusive and equitable use of AI in education;
- Leveraging AI to enhance education and learning;
- Promoting the development of skills for life in the age of AI, including teaching how AI works and its implications for humanity; and
- Safeguarding the transparent and auditable use of education data.

However, AI is not a magic bullet. There is much hyperbole to negotiate, and a large number of challenges to address.

The following overarching principle and policy recommendations also draw on the the Beijing Consensus (UNESCO, 2019a), which was agreed at the International Conference on AI and Education in Beijing (16-18 May 2019).

Accordingly, after setting out the overarching principle for AI and education policies, we make some recommendations as follows:

- Interdisciplinary **planning** and inter-sectoral **governance**;
- **policies** on equitable, inclusive, and ethical use of AI;
- develop a **master plan** for using AI for education management, teaching, learning, and assessment;
- pilot testing, **monitoring and evaluation**, and building an evidence base; and
- fostering **local AI innovations** for education.

ASSESS SYSTEM-WIDE READINESS AND CHOOSE STRATEGIC PRIORITIES

- **Consider the trade-offs on strategic priorities for education policy planning, including between the application of AI and other priorities, and between different focus areas or building blocks of the policies:** The trade-offs should be based on a thoughtful examination of the potential of AI technologies to support the achievement of the SDGs in the local context, moderated by the investment requirements for implementing policies and programmes centred on the application of AI in educational contexts. Thereafter, set strategic priorities based on an analysis of whether existing and emerging AI technologies are suitable solutions to the challenges of achieving SDG 4 and its targets. Consider other SDGs according to the urgency of developing the AI skills and values needed in all local sectors. Apply or create cost-value evaluation schemas to assess whether the educational benefits of implementing AI policies and programmes (e.g. increased effectiveness, enhanced efficiency, and expanded accessibility) outweigh the costs (e.g. infrastructure refurbishments, training, integration, and the risks of decreased trust and autonomy, lower-quality content, and the misuse of educational data.

→ EXAMPLES

The Global AI Strategy Landscape – Explores 50 National Artificial Intelligence strategies shaping the future of humanity: https://www.holoniq.com/notes/the-global-ai-strategy-landscape/; ***Deciphering China's AI Dream*** – The context, components, capabilities, and consequences of China's strategy to lead the world in AI (Ding, 2018): https://www.fhi.ox.ac.uk/wp-content/uploads/Deciphering_Chinas_AI-Dream.pdf

- **Define the strategic objectives of the policy based on system-wide readiness and cost-value assessment:** Apply or develop tools to assess system-wide AI readiness including infrastructure; Internet connectivity; the availability of data, AI tools, and local AI talent; the skills of key policy implementers; and stakeholders' awareness. When defining the time-bound goals, maintain realistic expectations of the benefits that AI systems are able to deliver, in the context of local systemic shortcomings in staffing levels, infrastructure and processes. Take into account the conceptual unknowns and limitations of educational paradigms that are likely to impact the capabilities of AI systems. Mitigate against the lack of systematic studies on the impact of AI in education.

→ EXAMPLE

Global AI Readiness Index: https://bit.ly/2UR2HXp

6.2 Overarching principle for AI and education policies

ADOPT A HUMANISTIC APPROACH AS AN OVERARCHING PRINCIPLE FOR AI AND EDUCATION POLICIES

- **Steer AI-and-education policy development and practices towards protecting human rights and equipping people with the values and skills needed for sustainable development and effective human-machine collaboration in life, learning and work;** Ensure that AI is human-controlled and centred on serving people, and that it is deployed to enhance capacities for students and teachers. Design AI applications in an ethical, non-discriminatory, equitable, transparent and auditable manner; and monitor and evaluate the impact of AI on people and society throughout the value chains.

- **Foster the human values needed to develop and apply AI.** Analyse the potential tension between market rewards and human values, skills, and social well-being in the context of AI technologies that increase productivity. Define values that prioritize people and the environment over efficiency, and human interaction over human-machine interaction. Foster broad corporate and civic responsibility for addressing the critical societal issues raised by AI technologies (such as fairness, transparency, accountability, human rights, democratic values, bias, and privacy). Ensure that people remain at the core of education as an implicit part of the technology design; and protect against automating tasks without identifying and compensating for the values of current practices.

→ **EXAMPLES**

AI for Humanity – French Strategy for Artificial Intelligence: https://www.aiforhumanity.fr/en/

EU Ethics Guidelines for Trustworthy AI: https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

OECD Principles on AI: https://www.oecd.org/going-digital/ai/principles

6.3 Interdisciplinary planning and inter-sectoral governance

MOBILIZE INTERDISCIPLINARY AND MULTI-STAKEHOLDER EXPERTISE TO INFORM POLICY PLANNING AND BUILD THE CAPACITIES OF POLICY-MAKERS

- **Build the knowledge and confidence of policy-makers and education managers so that they can navigate and make decisions in an increasingly AI-rich educational ecosystem:** Provide continuous training opportunities for decision-makers including finance planners, policy shapers, and policy implementation managers; facilitate expertise and best-practice exchange among stakeholders in and across countries; and align stakeholders' understandings of educational challenges to be addressed using AI technologies.

→ **EXAMPLE**

Elements of AI course: https://www.elementsofai.com

- **Infuse inter-sectoral, interdisciplinary and multi-stakeholder expertise to inform the key decisions in policy planning:** Bring together communities of expertise including educators, learning scientists and AI engineers from different areas of research such as neuroscience, cognitive science, social psychology, and the humanities, to design user-centred and result-based AI technologies that meet genuine classroom needs; reach out to international organizations to inform and advise on AI policy-making; and consider the potential of AI to combine and analyse multiple data sources to improve the efficiency of decision-making.

→ **EXAMPLE**

High-Level Expert Group on Artificial Intelligence, European AI Alliance: https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence

SET UP INTER-SECTORAL GOVERNANCE AND COORDINATION MECHANISMS

- **Adopt a whole-government and system-wide approach to the planning and governance of policies for the application of AI in educational contexts:** Coherent system-wide strategies and evidence-based inclusive approaches (such as participatory design and co-creation frameworks, Pobiner and Murphy, 2018) should be exploited to ensure that AI and education will be aligned and integrated with existing education policies and any broader national AI strategies; if a consensus is reached on the use of AI for the whole education system or broader inter-sectoral strategies, consider ways to adopt AI for system-wide transformation.

- **Set up a system-wide organizational structure for policy governance and coordination** to ensure that the implementation balances top-down and bottom-up methods, which involve the key partners and stakeholders maximizing their cross-sector collaboration and resource sharing. This should include a central governing board charged with commanding, supporting and overseeing the policy implementation; a coordination body to manage the partners and collaboration; and a team of representatives charged with implementing the policy. Most importantly, a comprehensive set of integrated principles on policy governance should be developed and consistently applied to allow the board to assume ownership and accountability.

→ **EXAMPLE**

Australia: https://education.nsw.gov.au/content/dam/main-education/teaching-and-learning/education-for-a-changing-world/media/documents/Future_Frontiers_discussion_paper.pdf.

- **Build an open and iterative cycle composed of key steps in planning, implementing, monitoring, and updating policy:** These steps should create a continuous learning process; monitoring and research should be integrated within the master plan focusing on concrete outcomes and gains in skills, knowledge and values. Monitoring and research must be communicated strategically and reach the decision-makers in order to feed back into a valid and robust evidence-informed foundation for development. The policy implementation process must be open to review and modification.

- **Promote the localization and reuse of open-source AI to incubate local development:** Curate open-source AI tools and platforms that can be tailored to the national and cultural context, key because so many AI technologies are proprietary intellectual property. Employ open-source strategies of sharing data and algorithms to incubate local innovations, and mitigate the digital divide between countries and within groups of learners.

> → **EXAMPLES**
>
> ***Global South AI Directory, Knowledge 4 All Foundation:*** https://www.k4all.org/;
> ***X5gon*** project (cross modal, cross cultural, cross lingual, cross domain, and cross site global OER network): https://www.x5gon.org/;
> ***Society 5.0 of Japan:*** https://www8.cao.go.jp/cstp/english/society5_0/index.html

6.4 Policies and regulations for equitable, inclusive, and ethical use of AI

SET OUT CROSS-CUTTING STRATEGIC OBJECTIVES, AND PLAN REGULATIONS AND PROGRAMMES, TO ENSURE THE EQUITABLE AND INCLUSIVE USE OF AI IN EDUCATION

- **Establish and monitor measurable targets to ensure inclusion, diversity and equality in teaching and developing AI services:** Identify those who stand to benefit from its implementation; strengthen appropriate infrastructure such as Internet access, hardware, and software to allow the equitable leveraging of educational AI benefits. Implement measures to reach out to the most vulnerable groups of society; and focus on educational AI that has a proven track record of including students with different backgrounds and abilities.

> → **EXAMPLE**
>
> ***Digital Bangladesh:*** https://a2i.gov.bd

- **Review AI's ability to either alleviate or exaggerate biases:** Reveal uncharted risks and mitigate against them; test AI tools and verify that they are free of biases (Pennington, 2018), and trained on data representative of diversity in terms of gender, disability, social and economic status, ethnic and cultural background, and geographic location. Foster mindsets that value fair and equitable AI that is respectful of such diversity. Stimulate a design approach that incorporates ethics, privacy, and security into the research and development of AI in education.

- **Create AI applications that are free from gender biases and ensure that the data used for development are gender-sensitive:** Incentivize AI applications that promote gender equality; empower girls and women with AI skills to increase gender equality among workforces and employers.

> → **EXAMPLE**
>
> UNESCO's publication ***'I'd blush if I could'***, which shares strategies for closing gender divides in digital skills: https://unesdoc.unesco.org/ark:/48223/pf0000367416

- **Establish data protection laws which make educational data collection and analysis visible, traceable, and auditable by teachers, students and parents:** Formulate clear policies regarding data ownership, privacy and availability for the public good. Follow international guidelines created by expert groups around wider AI data issues; and abide by internationally recognized ethics.

> → **EXAMPLES**
>
> The ***General Data Protection Regulation*** applicable as of 25 May 2018 in all EU member states to harmonize data privacy laws across Europe: https://gdpr-info.eu/;
>
> ***Ethics guidelines for trustworthy AI***, European Union: https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

- **Investigate options for striking a balance between open access and data privacy:** Test and adopt emerging AI technologies and tools for ensuring teachers' and learners' data privacy and security. Develop comprehensive regulatory frameworks to guarantee the ethical, non-discriminatory, equitable, transparent and auditable use and reuse of learners' data.

- **Facilitate open debates on issues related to AI ethics, data privacy and security, and concerns about AI's negative impact on human rights and gender equality:** Ensure that AI is used for good and prevent its harmful applications. Address the complex issue of informed consent – particularly in educational contexts where many of the users (e.g. children and students with learning difficulties) are not capable of giving genuinely informed consent.

> → **EXAMPLE**
>
> ***DataKind***, which advocates for social organizations to have the same access to data science resources as large technology companies: https://www.datakind.org

6.5 Master plans for using AI in education management, teaching, learning, and assessment

LEVERAGE AI TO BOOST AND UPGRADE EDUCATION MANAGEMENT AND DELIVERY

- **Explore how AI technologies can improve educational management information systems (EMIS):** Leverage AI to make EMIS more robust, accessible, streamlined, capable, user-friendly and efficient. Gear the evidence-based decision-making and management towards a more flexible, dynamic and democratized set of processes and data flows that are more responsive to changes in social and educational paradigms. Invest in the possibility of leveraging AI capabilities to enable system-wide predictions about skills and demand, to allow governments to prepare to meet relevant local educational needs and integrate them with sectors such as finance, economics, law and medicine.

→ EXAMPLE

The Open University's ***OU Analyse***, which predicts student outcomes and identifies students at risk of failing by analysing big data from the university's EMIS: https://analyse.kmi.open.ac.uk

- **Enable the holistic transformation of EMIS and their integration with learning management systems (LMS):** Ensure EMIS are kept up to date with changes triggered by AI-powered pedagogy, providing the means to integrate LMS with EMIS to support progress towards more comprehensive, rich, well-rounded means of evaluation.

→ EXAMPLE

Zhixue (Intelligent Learning), a LMS developed by iFlyTek of China to enable personalized online tutorial courses: https://www.zhixue.com/login.html

- **Empower managers, teachers and students to promote the application of AI-powered EMIS and LMS:** Analyse the cost of introducing AI-powered EMIS and LMS into schools. Ensure low-cost entry for school managers and teachers so that they can see benefits rather than increased administrative tasks. Set up and monitor visible, transparent processes of automatically collecting data on teachers' practices and students' activities. Promote the use of AI to support personalized resources and outcomes, so that learners can have personal insights and leverage their skills and knowledge across contexts while staying in control of their own data and digital identities.

→ EXAMPLE

LabXchange by Amgen Foundation and Harvard University's Faculty of Arts and Sciences, a free online science education platform that provides users with personalized instruction, virtual lab experiences, and networking opportunities across the global scientific community: https://www.multivu.com/players/English/8490258-amgen-foundation-harvard-labxchange

CULTIVATE LEARNER-CENTRED USE OF AI TO ENHANCE LEARNING AND ASSESSMENT

- **Reinforce and reiterate humans' authority and autonomy over their own learning in the context of increasingly knowledgeable machines and computer agents:** Consult teachers and students about their views on AI technologies and use the feedback to decide how AI should be deployed in learning environments. Inform students about the types of data collected on them, how these are used, and the impact this may have on their learning, careers and social lives. Prevent institutions from using AI technologies for surveillance purposes – instead, cultivate trust among students and use AI for bolstering their progress instead of increasing scrutiny.

- **Emphasize students' agency and social well-being in the process of integrating AI-based tools:** Protect students' agency and motivation to grow as individuals; protect play and leisure time, social interaction, and school breaks. Use AI-based tools to minimize the pressure of homework and exams, rather than exacerbating it. Support students to adapt to new AI tools and methodologies so that these can have a positive impact on their learning; and allow them to make observations and give feedback on the challenges created by the use of AI in the classroom.

→ EXAMPLES

AlphaEgg, an intelligent robot for child care, developed by iFlyTek: https://ifworlddesignguide.com/entry/203859-alphaegg;

The CoWriter: Learning to write with a robot, developed by CHILI (Computer-Human Interaction in Learning and Instruction), EPFL Technical University, Switzerland: https://www.epfl.ch/labs/chili/index-html/research/cowriter; https://www.youtube.com/watch?v=E_iozVysl5g

- **Review and adjust curricula to reflect pedagogical and assessment changes brought by the increasingly wide adoption of AI in teaching and learning:** Collaborate with AI providers and educators to identify the most appropriate ways of responding to changes in curriculum frameworks and assessment methodologies, to provide an enabling policy environment and curricular spaces for exploring AI. Facilitate the participation of student representatives in countrywide initiatives that promote new competencies in the curriculum.

→ EXAMPLE

Digital Education, Programming and Robotics for all Argentine students: https://www.argentina.gob.ar/educacion/aprender-conectados/nucleos-de-aprendizajes-prioritarios-nap

- **Test and deploy AI technologies to support the assessment of multiple dimensions of competencies and outcomes:** Integrate AI into psychometric assessments, possibly including chatbot-type conversations with students in situational judgment tests. Avoid using AI as the sole means of predicting students' future educational and career development. Use caution when adopting algorithm-based automatic grading of responses to 'rule-based' closed questions; support teachers to use AI-based formative assessment as an integrated function of AI-powered LMS to analyse data on students' learning with higher precision and efficiency and reduced human bias. Explore the potential of AI-based progressive assessments to provide regular updates for teachers, students and parents. Using a humanistic perspective, test and evaluate the use of facial recognition and other AI for user authentication and invigilation in remote online assessments.

→ **PARTIAL EXAMPLE**

Towards AI-based assessment systems: https://www.researchgate.net/publication/314088884_Towards_artificial_intelligence-based_assessment_systems

ENSURE THAT AI IS USED TO EMPOWER TEACHERS

Protect the rights of teachers and the value of their practices: Conduct consultations with educators to ensure their rights are protected and their opinions are taken into account when deploying AI technologies. Carry out pilot studies and at-scale trials focused on attending to teachers' daily practical requirements when integrating AI technologies; facilitate the development of AI tools to support teaching rather than to replace core teacher functions. Provide evidence-based guidance that allows teachers to navigate the private-sector offerings of AI-based technologies; and develop criteria and ratings to help them make informed decisions on what tools are most suitable for their needs.

- **Analyse and review teachers' roles in facilitating knowledge transfer, human interaction, higher-order thinking, and human values:** Analyse the benefits of automating certain tasks against the risks of reducing or harming learning practices. Mitigate against the automation of tasks that are time-consuming but also informative for teachers; identify concrete aspects that rely on teachers' autonomy and motivation; preserve and enhance these elements in the process of introducing AI into pedagogical practices, and maintain a high level of trust in teachers' authority and capabilities.

- **Define the skill sets that teachers need in order to search for and apply AI tools in their design and organization of learning activities and in their own professional development:** Analyse the skills needed for human-machine collaboration in teaching environments. Evaluate the paradigm changes that are required for applying AI to teachers' professional development, administration of AI-based assessment, and design and implementation of AI-enhanced learning activities. Update teachers' frameworks and training programmes with reference to the UNESCO ICT Competency Framework for Teachers (UNESCO, 2018).

- **Deliver training and ensure continuous support to help teachers gain skills to use AI effectively:** Develop and deliver training programmes on the required skills before deploying AI platforms or tools; prevent situations where teachers are left unable to conduct their role due to unavailable or unreliable AI functionality. Plan ahead to enable teachers to apply new AI technologies to their current practices and transition to new ways of working; encourage the formation of communities of educators who share experiences and day-to-day best practice and foster innovative uses of AI tools. Provide simplified guidelines based on emerging technology research to update teachers on the latest findings that they might apply in classroom settings, and increase lifelong-learning opportunities for teachers to keep up with the changes brought by AI inside and outside of the classroom.

→ **EXAMPLES**

UNESCO ICT Competency Framework for Teachers: https://unesdoc.unesco.org/ark:/48223/pf0000265721;

Resources on AI in K-12 education, International Society for Technology in Education (ISTE): https://www.iste.org/learn/AI-in-education

PLAN THE USE OF AI TO SUPPORT LIFELONG LEARNING ACROSS AGES, LOCATIONS AND BACKGROUNDS

- **Actively seek and promote the use of AI to support a wide range of educational approaches and diverse pathways for lifelong learning:** Initiate and sustain the ability of institutions to leverage AI to become more dynamic, serve higher numbers of non-traditional learners, and provide lifelong learning across formal, non-formal and informal settings. Suggest viable mechanisms for traditional institutions to move towards hybrid methods, combining face-to-face teaching with dynamically evolving, AI-powered courses; and provide incentives for partnerships between institutions and AI providers, to foster the development of AI tools that maximize opportunities for lifelong learning.

- **Build AI tools and systems to track learning outcomes and credentials across levels and locations of study:** Develop AI platforms, tools and systems to track learning outcomes and enable easier skill specialization; and explore ways to use AI to expand the availability of educational credentials and qualification pathways.

→ **PARTIAL EXAMPLES**

SkillsFuture initiative, Singaporean Government: https://www.skillsfuture.gov.sg; OpenCert (Singapore), which supports the verification of lifelong-learning certificates obtained from 'any' institution: https://opencerts.io

- **Address imbalances in access to AI across age groups:** Set up campaigns to combat barriers to entry for the most vulnerable groups, including older people, and initiate projects that generate interest in AI among learners of different ages and backgrounds.

DEVELOP VALUES AND SKILLS FOR LIFE AND WORK IN THE AI ERA

- **Build prediction models to identify trends in employment and skills, and develop retraining programmes for those in jobs at risk of AI automation:** Identify the social costs of job automation, and increase public awareness of the resulting national and global shifts in skills demand. Establish a national focus on enhancing future-proof skills at all levels of education; provide options for re-skilling pathways and build resilience in the workforce to cope with the systemic and long-term transformation of the labour market. Provide special protections for older workers who may find it more challenging to learn new skills and adapt to new environments. Encourage training programmes to include a focus on how AI will impact every profession.

→ **EXAMPLE**

CEDEFOP Skills Forecast: EU tool for skills prediction and preparation: https://www.cedefop.europa.eu/en/publications-and-resources/data-visualisations/skills-forecast

- **Integrate AI-related skills into school curricula and technical and vocational education and training (TVET) qualifications:** Enact changes in curricula to prepare students for the future, ensuring their relevance to shifting economies, labour markets and societies across all subjects and competencies. Develop courses, programmes and qualifications to provide awareness and expertise around how AI technologies work, their ethical implications, and how they should be designed. Support the development of tools for learning about AI that are underpinned by pedagogical research and sound methodologies.

→ **EXAMPLES**

The Wekinator, a free, open-source software created by Rebecca Fiebrink, with which one may use machine learning to build new musical instruments, gestural game controllers, and computer vision and listening systems: http://www.wekinator.org/

Teaching AI for K12, a portal created by UNESCO and Ericsson of links to free resources that teachers can use to teach about AI, plus some information to help teachers learn about AI: http://teachingaifork12.org

- **Take institutional actions to enhance AI literacy across all sectors of society:** Provide basic AI education to all citizens, educating them on thinking critically and responsibly about their choices, rights and privileges in the context of AI and its impact on their day-to-day lives. Inform them on how to protect their privacy and control their own data and decisions. Dismantle the myths and hype around AI by educating the population about its limitations, as well as the differences between AI and human intelligence. Carefully integrate emerging AI literacy skills with existing foundational skills such as media and information literacies, and identify ways of merging the different required literacies to prevent overloading the curricula.

→ **EXAMPLE**

1 Percent: Finland's plan to train its population in AI: https://www.politico.eu/article/finland-one-percent-ai-artificial-intelligence-courses-learning-training/

- **Help higher education and research institutions to foster local AI talent:** Set up plans to help higher education and research institutions build or enhance programmes to develop local AI talent, and create a gender-balanced pool of professionals from diverse socio-economic backgrounds who have the expertise to design AI systems. Develop executive master programmes to reskill engineers in AI, and incentivize engineering companies to invest in retraining their workforces in AI.

- **Retain local AI talent:** Incentivize AI companies to base themselves locally; mitigate against regional differences in salaries and rewards; and retain AI professionals by providing interesting intellectual challenges and a good work-life balance.

→ **EXAMPLES**

Next AI, a programme delivered on campuses in Toronto and Montréal in Canada to identify talented teams and leverage Canada's resources and provide them with the necessary capital, mentorship, education and network: https://www.nextcanada.com/next-ai/;

A Chinese Government initiative to train 500 university teachers and 5,000 students in AI: https://www.ecns.cn/2018/04-07/298280.shtml

6.6 Pilot testing, monitoring and evaluation, and building an evidence base

BUILD A TRUSTED EVIDENCE BASE TO SUPPORT THE USE OF AI IN EDUCATION

- **Test and scale up evidence-based avenues of applying AI in learning:** In accordance with educational priorities, rather than novelty or hype, encourage the pilot testing and evidence-informed adoption of technologies such as AI-enhanced personalized learning models, dialogue-based tutoring systems, exploratory learning systems, automatic writing evaluation systems, language learning tools, AI-based artwork and music generators, chatbots, augmented and virtual reality tools, and learning network orchestrators. Incentivize the adoption of AI tools that encourage open-ended, exploratory and diverse learning environments. Foster broad, transferable abilities including social-emotional skills, meta-cognition, collaboration, problem-solving, and creativity. Ensure that the application of AI in education is strategic (i.e. has long-term pedagogical aims) rather than short-term or ad hoc.

→ EXAMPLES

ITalk2Learn, a three-year collaborative European project (Nov 2012 – Oct 2015) that aimed to develop an open-source intelligent tutoring platform that supports maths learning for students aged 5 to 11: https://www.italk2learn.com/;

FractionsLab, UK, an exploratory learning environment to teach fractions with AI-driven feedback: http://fractionslab.lkl.ac.uk;

Squirrel AI Learning, developed by China's Yixue Group, an adaptive learning engine based on the pattern recognition algorithm: http://squirrelai.com/; https://www.technologyreview.com/s/614057/china-squirrel-has-started-a-grand-experiment-in-ai-education-it-could-reshape-how-the/;

SmartMusic, a web-based suite of music education tools that support musicians' practice and development: https://www.smartmusic.com/;

AIArtists.org, which provides creative tools to generate AI art: https://aiartists.org/ai-generated-art-tools

- **Establish AI-specific criteria based on proven pedagogical research and methodologies, to systematically and rigorously verify vendors' claims about AI's potentials:** Develop AI-specific criteria catering for the human, social and ethical concerns that relate to each of the three core components of applying AI in education: data, algorithmic analyses, and educational practices.

- **Facilitate local pilot evaluations of AI systems to evaluate their relevance and effectiveness:** Design and conduct large-scale pilot evaluations of AI systems supplied by external providers. Test whether they are relevant to the local context and effective in terms of educational practices, objectives, diversity, culture, and demographics. Use the results to customize the AI system's data, design and integration in response to local needs. Monitor the application of the system to protect against conflicts in interests or partnerships, and discrepancies related to data protection or ownership.

- **Calculate and analyse the environmental cost of leveraging AI technologies at scale:** Develop sustainable targets to be met by AI corporations in a bid to avoid contributing to climate change and damage to the natural environment. Incentivize environmentally friendly means of producing the energy and resources required for large-scale AI deployment.

STRENGTHEN RESEARCH AND EVALUATION IN THE FIELD OF AI AND EDUCATION

- **Enable the use of AI to promote and improve educational research and innovation:** Leverage AI data collection practices and methodologies to improve research on education technologies. Draw lessons from successful cases and scale up evidence-based practices.

- **Review the comprehensive impacts of AI on education:** Exploit research and review processes to fully understand the social and ethical implications of incorporating AI into local educational contexts; conduct critical reviews of uncharted challenges and risks, including changes in teacher-student and student-student collaboration and social dynamics.

- **Encourage investment and provide targeted funding in order to build an evidence-based ecosystem for AI in education:** Help stimulate and support the research and development of AI applications in the commercial and university sectors, enhancing local expertise while minimizing the influence of vested interests.

- **Fund and incentivize research on AI and education outside the realm of government- and corporate-driven development:** Protect the evolution and expansion of local AI-in-education expertise within research and university settings, and minimize the influence of vested interests on what AI is developed and how it is evaluated.

→ EXAMPLE

International Research Centre on Artificial Intelligence (IRCAI) under the auspices of UNESCO, whose mission is to undertake research, advocacy, capacity-building and dissemination of information about AI. https://ircai.org/

6.7 Fostering local AI innovations for education

PROMOTE THE LOCAL DEVELOPMENT OF AI TECHNOLOGIES FOR EDUCATION

- **Attract corporate investment and provide funding to create an evidence base:** Help stimulate and support the development of human-centric AI-in-education tools, bringing together learners, funders, commercial developers, educators, and learning scientists, in order to address market failures, the complexity of educational practices worldwide, and the challenges of scaling initiatives.

- **Foster innovations and incubate the local development of AI technologies and tools:** Synergize expertise, resources and capacities, and leverage evidence-driven research methodologies across corporate AI design. Generate independent evaluations of consumer-targeted AI and encourage progress towards an aligned, human-centric future for AI development. Invest in the education and training of local talent and build an appetite for AI start-up ecosystems to be formed locally, within a network of investment and access to labour and consumer markets. Engage in international collaborations to build resources and capacity for deploying AI-based technologies at scale, to enable the development of local AI tools and expertise.

→ EXAMPLE

IBM Research–Africa is IBM's 12th global research lab and the continent's first industrial research facility. It is driving innovation by developing commercially viable solutions to transform lives and spark new business opportunities in key areas including education: https://www.research.ibm.com/labs/africa

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Notes

1 More detailed non-technical guidance for policy-makers has been produced by the 'AI for Peace' group: https://www.aiforpeace.org/library

2 A quintillion equals 1,000,000,000,000,000,000

3 The computing power requires large amounts of energy with significant implications for the world's climate.

4 https://www.gehealthcare.com/article/artificial-intelligence-helps-doctors-with-critical-measurement-during-pregnancy

5 https://ai.googleblog.com/2018/12/improving-effectiveness-of-diabetic.html

6 https://www.nytimes.com/2019/05/20/health/cancer-artificial-intelligence-ct-scans.html

7 For example, researchers overlaid an image of a panda, that the AI tool correctly recognized, with some random noise. The image was still easily recognizable to a human as a panda, but the AI tool identified it as showing a gibbon. Similarly, sticking some small pieces of paper randomly on a road sign, such as a stop sign, can lead autonomous vehicles to misidentify it.

8 A seminal book that introduces much of this complexity is Russell and Norvig (2016)

9 https://www.mturk.com

10 https://www.ft.com/content/a4b6e13e-675e-11e5-97d0-1456a776a4f5

11 https://thispersondoesnotexist.com

12 https://otter.ai

13 https://www.alibabacloud.com/products/machine-translation

14 https://lens.google.com

15 https://woebothealth.com

16 https://www.affectiva.com

17 https://www.frontiersin.org/articles/10.3389/fnhum.2019.00076/full

18 https://cs.nyu.edu/faculty/davise/papers/GPT3CompleteTests.html

19 The introduction of chatbots to answer customers' banking queries suggests that even here things are beginning to change (https://www.scmp.com/business/companies/article/2128179/hsbcs-amy-and-other-soon-be-released-ai-chatbots-are-about-change). However, Google's infamous Duplex technology now seems to be less intelligent than it first appeared.

20 https://www.apple.com/uk/siri/

21 https://www.digitaltrends.com/home/what-is-amazons-alexa-and-what-can-it-do/

22 https://dueros.baidu.com/en/index.html

23 https://www.gearbest.com/blog/tech-news/huawei-releases-ai-smart-speaker-mini-with-xiaoyi-voice-assistant-in-china-6420

24 https://www.jisc.ac.uk/news/chatbot-talks-up-a-storm-for-bolton-college-26-mar-2019

25 http://genie.deakin.edu.au

26 https://analyse.kmi.open.ac.uk

27 https://www.swiftelearningservices.com/learning-analytics-big-data-in-elearning

28 http://kidaptive.com

29 https://www.unitime.org

30 https://moodle.org

31 https://open.edx.org

32 https://www.khanacademy.org

33 For example, Bayesian Knowledge Tracing or Performance Factors Analysis

34 Alef: https://alefeducation.com

35 ALEKS: https://www.aleks.com

36 Byjus: https://byjus.com (NB Not available in Europe)

37 Mathia: https://www.carnegielearning.com

38 Qubena: https://qubena.com

39 Riiid: https://riiidlabs.ai/

40 Squirrel AI: http://squirrelai.com

41 https://educationcommission.org

42 Watson Tutor: https://www.ibm.com/blogs/watson/2018/06/using-ai-to-close-learning-gap/

43 See https://theconversation.com/artificial-intelligence-can-now-emulate-human-behaviors-soon-it-will-be-dangerously-good-114136. And, for an early example of AI that can 'write' a school assignment, see https://openai.com/blog/better-language-models/#sample6

44 WriteToLearn: https://www.pearsonassessments.com/professional-assessments/products/programs/write-to-learn.html

45 e-Rater: https://www.ets.org/erater/about

46 Turnitin: https://www.turnitin.com

47 Smartmusic: https://www.smartmusic.com

48 AI Teacher: http://aiteacher.100tal.com

49 'Amazing English' uses AI to help students practise their English aloud. It also provides real-time feedback and AI-driven assessments. See https://www.prnewswire.com/news-releases/xueersi-online-school-releases-dual-teacher-product-offering-more-english-speaking-time-than-one-on-one-teaching-300626008.html

50 Babbel: https://www.babbel.com

51 Duolingo: https://www.duolingo.coml

52 https://elearningindustry.com/telepresence-in-education-future-elearning

53 https://www.softbankrobotics.com/emea/en/nao

54 https://www.softbankrobotics.com/emea/en/pepper

55 https://www.youtube.com/watch?v=E_iozVysl5g

56 https://www.blippar.com

57 https://eonreality.com/eon-reality-education

58 https://edu.google.com/products/vr-ar

59 http://www.neobear.com

60 http://www.vrmonkey.com.br

61 https://thirdspacelearning.com

62 http://slp.bnu.edu.cn

63 https://www.mofaxiao.com/

64 https://tesla-project.eu

65 Open, distributed ledgers, hosted simultaneously by millions of computers across the Internet and linked using cryptography, that can share data in a verifiable, incorruptible, and accessible way.

66 e.g. Ada Lovelace Institute (https://www.adalovelaceinstitute.org), AI Ethics Initiative (https://aiethicsinitiative.org), AI Ethics Lab (http://www.aiethicslab.com), AI Now (https://ainowinstitute.org), DeepMind Ethics and Society (https://deepmind.com/applied/deepmind-ethics-society), and the Oxford Internet Institute (https://www.oii.ox.ac.uk/blog/can-we-teach-morality-to-machines-three-perspectives-on-ethics-for-artificial-intelligence). Also see Winfield, Alan F. T., and Jirotka, M. 2018. Ethical governance is essential to building trust in robotics and artificial intelligence systems. Phil. Trans. R. Soc. A. 376. And see "Top 9 ethical issues in artificial intelligence." Available at: https://www.weforum.org/agenda/2016/10/top-10-ethical-issues-in-artificial-intelligence, "Establishing an AI code of ethics will be harder than people think." Available at: https://www.technologyreview.com/s/612318/establishing-an-ai-code-of-ethics-will-be-harder-than-people-think, and Willson, M. 2018. Raising the ideal child? Algorithms, quantification and prediction. Media, Culture & Society, 5.

67 https://www.brainco.tech and see https://www.independent.co.uk/news/world/asia/china-schools-scan-brains-concentration-headbands-children-brainco-focus-a8728951.html

68 For example, see the XPrize (https://learning.xprize.org).

69 https://digitallibrary.io

70 https://www.changedyslexia.org

71 e.g. http://www.voiceitt.com, https://www.nuance.com, https://otter.ai and https://kidsense.ai

72 https://blogs.microsoft.com/ai/ai-powered-captioning/

73 https://consumer.huawei.com/uk/campaign/storysign/

74 An example of a robot developed for children on the autism spectrum is Kaspar (Dautenhahn *et al.*, 2009)

75 See, for example, Bughin *et al.*, 2017; Frey and Osborne, 2017; Frontier Economics, 2018; Leopold *et al.*, 2018; Madgavkar *et al.*, 2019; and Manyika *et al.*, 2017.

76 Manpower Group. 2016. Millennial Careers: 2020 Vision- Facts, figures and practical advice from workforce experts. Available at https://www.manpowergroup.com/wps/wcm/connect/660ebf65-144c-489e-975c-9f838294c237/MillennialsPaper1_2020Vision_lo.pdf?MOD=AJPERES

77 See, for example: (Tencent Research Institute, 2017) 全球人工智能人才白皮书

78 Courses designed to enable citizens to become familiar with how AI works can be found at https://www.elementsofai.com, https://okai.brown.edu and http://ai-4-all.org.

79 Resources designed to help teachers introduce their students to AI can be found at http://teachingaifork12.org and https://github.com/touretzkyds/ai4k12/wiki

80 http://www.gettingsmart.com/2018/07/coming-this-fall-to-montour-school-district-americas-first-public-school-ai-program

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AI and education

Guidance for policy-makers

Artificial intelligence (AI) is envisioned as a new tool to accelerate the progress towards the achievement of SDG 4. Policies and strategies for using AI in education are central to maximizing AI's benefits and mitigating its potential risks. Fostering AI-ready policy-makers is the starting point of the policy development process.

This publication offers guidance to policy-makers in understanding AI and responding to the challenges and opportunities in education presented by AI. Specifically, it introduces the essentials of AI such as its definition, techniques, technologies, capacities and limitations. It also delineates the emerging practices and benefit-risk assessment on leveraging AI to enhance education and learning, and to ensure inclusion and equity, as well as the reciprocal role of education in preparing humans to live and work with AI.

The publication summarizes three approaches to the policy responses from existing practices: independent approach, integrated approach and thematic approach. In a further step, it proposes more detailed recommendations and examples for planning AI and education policies, aligned with the recommendations made in the 2019 *Beijing Consensus on AI and Education*.

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4 QUALITY EDUCATION

Sustainable Development Goals