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Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development

Education 2030

Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development

UNESCO Education Sector

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Abstract

Artificial Intelligence is a booming technological domain capable of altering every aspect of our social interactions. In education, AI has begun producing new teaching and learning solutions that are now undergoing testing in different contexts. This working paper, written for education policymakers, anticipates the extent to which AI affects the education sector to allow for informed and appropriate policy responses. This paper gathers examples of the introduction of AI in education worldwide, particularly in developing countries, discussions in the context of the 2019 Mobile Learning Week and beyond, as part of the multiple ways to accomplish Sustainable Development Goal 4, which strives for equitable, quality education for all.

First, this paper analyses how AI can be used to improve learning outcomes, presenting examples of how AI technology can help education systems use data to improve educational equity and quality in the developing world. Next, the paper explores the different means by which governments and educational institutions are rethinking and reworking educational programmes to prepare learners for the increasing presence of AI in all aspects of human activity. The paper then addresses the challenges and policy implications that should be part of the global and local conversations regarding the possibilities and risks of introducing AI in education and preparing students for an AI-powered context.

Finally, this paper reflects on future directions for AI in education, ending with an open invitation to create new discussions around the uses, possibilities and risks of AI in education for sustainable development.

Executive Summary

Artificial Intelligence is a booming technological domain capable of altering every aspect of our social interactions. In education, AI has begun producing new teaching and learning solutions that are now undergoing testing in different contexts. AI requires advanced infrastructures and an ecosystem of thriving innovators, but what about the urgencies of developing countries? Will they have to wait for the "luxury" of AI? Or should AI be a priority to tackle as soon as possible to reduce the digital and social divide?

These are some of the questions guiding this document. In this regard, this urgent discussion should be taken up with a clear picture of what is happening and what can be done. This document gathers examples of how AI has been introduced in education worldwide, particularly in developing countries. It also sows the seeds of debates and discussions in the context of the 2019 Mobile Learning Week and beyond, as part of the multiple ways to accomplish Sustainable Development Goal 4, which targets education.

This document was drawn up for education policymakers and anticipates the extent to which AI affects the education sector so that informed and appropriate policy responses can be made in this regard.

The *first section* of this document analyses how AI can be used to improve learning outcomes. It presents examples of how AI technology can help education systems use data to improve educational equity and quality in the developing world. The section is divided into two topics that address pedagogical and system-wide solutions:

i) AI to promote personalisation and better learning outcomes, exploring how AI can favour access to education, collaborative environments and intelligent tutoring systems to support teachers. We briefly introduce cases from countries such as China, Uruguay, Brazil, South Africa and Kenya as examples experimental solutions conceived from public policies, philanthropic and private organisations.

ii) Data analytics in Education Management Information Systems (EMIS). Here we present opportunities for improving a state's capacity to manage large-scale educational systems by increasing data from schools and learning, presenting cases from United Arab Emirates, Kenya, Bhutan, Kyrgyzstan and Chile.

The *second section* "Preparing learners to thrive in an AI-saturated future" explores the different means by which governments and educational institutions are rethinking and reworking educational programmes to prepare learners for the increasing presence of AI in all aspects of human activity. Based on examples from different contexts, the section is also divided into two main parts:

i) "A new curriculum for a digital and AI powered world" elaborates further on the importance of advancing in digital competency frameworks for teachers and students. Some current initiatives are presented such as the "Global Framework to Measure Digital Literacy" and "ICT Competencies and Standards from the Pedagogical Dimension". The discussion of the curricular dimension is broadened to include new experiences for developing computational thinking in schools with examples from the European Union, United Kingdom, Estonia, Argentina, Singapore and Malaysia.

ii) The second part is more focused on strengthening AI capacities through post-basic education and training. How can each country prepare the conditions for an AI-powered world? Here we present some of the most advanced cases from developed countries who are generating comprehensive plans to tackle this question, namely France, South Korea and China. We also present some cases from the technical and vocational education and training sector and some opportunities from non-formal and informal learning scenarios.

The *last section* addresses the challenges and policy implications that should be part of the global and local conversations regarding the possibilities and risks of introducing AI in education and preparing students for an AI-powered context. Six challenges are presented:

The first challenge lies in developing a comprehensive view of public policy on AI for sustainable development. The complexity of the technological conditions needed to advance in this field require the alignment of multiple factors and institutions. Public policies have to work in partnership at international and national levels to create an ecosystem of AI that serves sustainable development.

The second challenge is to ensure inclusion and equity for AI in education. The least developed countries are at risk of suffering new technological, economic and social divides with the development of AI. Some main obstacles such as basic technological infrastructure must be faced to establish the basic conditions for implementing new strategies that take advantage of AI to improve learning.

The third challenge is to prepare teachers for an AI-powered education while preparing AI to understand education, though this must nevertheless be a two-way road: teachers

must learn new digital skills to use AI in a pedagogical and meaningful way and AI developers must learn how teachers work and create solutions that are sustainable in real-life environments.

The fourth challenge is to develop quality and inclusive data systems. If we are headed towards the datafication of education, the quality of data should be our chief concern. It´s essential to develop state capabilities to improve data collection and systematisation. AI developments should be an opportunity to increase the importance of data in educational system management.

The fifth challenge is to make research on AI in education significant. While it can be reasonably expected that research on AI in education will increase in the coming years, it is nevertheless worth recalling the difficulties that the education sector has had in taking stock of educational research in a significant way both for practice and policy-making.

The sixth challenge deals with ethics and transparency in data collection, use and dissemination. AI opens many ethical concerns regarding access to education system, recommendations to individual students, personal data concentration, liability, impact on work, data privacy and ownership of data feeding algorithms. AI regulation will thus require public discussion on ethics, accountability, transparency and security.

The document ends with an open invitation to create new discussions around the uses, possibilities and risks of AI in education for sustainable development.

Introduction

In this age of big data, we all leave behind individual information footprints, resulting in an abundance of data, allowing human and societal behaviour to be objectively quantified and, therefore, easily tracked, modelled and, to a certain extent, predicted. This phenomenon surrounding information footprints is referred to as 'datafication' (Mayer-Schönberger & Cukier, 2014) and also affects the education sector. While datafication certainly raises some ethical concerns, which also require a concerted policy response, it also brings a world of possibilities in terms of individualising learning and education governance. To date, little has been discussed about the possibilities and limitations of AI in education in the developing world, particularly regarding the extreme problems of the least developed countries. With a view to helping bridge this gap, this paper will discuss AI technologies that education systems worldwide are beginning to use and also explore how they have helped or can help improve learning outcomes.

In this context, this paper aims to identify the education policy implications of AI by examining four main challenges:

1. Ensuring inclusive and equitable use of AI in education
2. Leveraging AI to enhance education and learning
3. Promoting skills development for jobs and life in the AI era
4. Safeguarding transparent and auditable use of education data

This paper was drawn up to assist education policymakers, specifically in developing countries, in understanding and anticipating the extent to which AI impacts the education sector so they can determine appropriate policy responses. By examining the education sector's response to AI in various countries, this paper suggests critical considerations for public policies in developing countries to integrate AI-powered technologies. The overall goal is to ensure that learners acquire the competencies to thrive in an AI-powered society. In doing so, this paper also elaborates on the key risks and challenges that countries are facing in steering the use and development of AI.

This document was also drawn up to open urgent discussions on the role of AI in education in developing countries. To do so, this document is broad and simple in its style, open and careful in its suggestions, and full of examples to tackle these discussions in dialogue with real-world applications as they unfold in the present.

Given the complexity of the topic with changes happening at an exponential and unpredictable rate, public policy discussions have been elicited but postponed by the surrounding urgencies educational systems face worldwide. Nevertheless, in a world that is becoming AI-powered, education must prioritise this discussion for the public policy agenda in every context.

This paper is divided into three sections.

Section I, "Leveraging AI towards improving learning outcomes", presents examples of how AI technology can help education systems use data to improve teaching in the developing world. This section comprises two sub-sections that address pedagogical and system-wide

solutions, namely (1) AI to promote personalisation and better learning outcomes, and (2) Data analytics in Education Management Information Systems (EMIS).

Section II, "Preparing learners to thrive in an AI-saturated future", explores different means by which governments and educational institutions are rethinking and reworking learning programmes to prepare learners for the increasing presence of AI in all aspects of human activity. It is based on examples from different contexts and also divided in two subsections, namely (1) A new curriculum for a digital and AI-powered world, and (2) Strengthening AI capacities through post-basic education and training.

Section III, "Challenges and policy implications ". The last section addresses the challenges and policy implications that need to be part of the global and local conversations surrounding the possibilities and risks of introducing AI in education and preparing students for an AI-powered context.

A brief introduction to AI

Since its 'birth' at the 1956 Dartmouth Conference, the field of artificial intelligence (AI) has continued garnering the interest of a and industries alike. Few technological developments in recent history have been as polarising as AI. While AI has be en around for nearly 60 years, it nevertheless remained a fringe technology until only recently because of sweeping changes in recent years (referred to as "the big leap"), entailing the abundance of data (big data), economic access to computing power and advances in Machine Learning. The present paper uses terms such as AI and Big Data, the two main technology buzzwords of the current decade, and other concepts such as machine learning, learning analytics, etc. as technologies that work well together. It should be borne in mind that these terms are sometimes used interchangeably in the news and articles, thus creating confusion. With a view to avoiding such confusion, this subsection contains a brief explanation of these concepts, clarifying their differences and how they work together (there is also a complementary definition in the annex hereto).

While there is no straightforward and consensual definition of AI, several classic definitions of AI are nevertheless provided from the different literature, including McCarthy (2006), Zhong (2006), ITU (2018).

In this paper, AI is best understood considering different dimensions **(see Figure 1)**

Figure 1. Different dimensions of AI

Thinking Humanly

'The exciting new effort to make computers think… *machines with minds*, in the full and literal sense.' (Haugeland, 1985)

'[The automation of] activities that we associate with human thinking, activities such as decision-making, problem-solving, learning…' (Bellman, 1978)

Thinking Rationally

'The study of mental faculties through the use of computational models.' (Charniak & McDermott, 1985)

'The study of the computations that make it possible to perceive, reason, and act.' (Winston, 1992)

Acting Humanly

'The art of creating machines that perform functions that require intelligence when performed by people.' (Kurzweil, 1990)

'The study of how to make computers do things at which, at the moment, people are better.' (Rich & Knight, 1991)

Acting Rationally

'Computational Intelligence is the study of the design of intelligent agents.' (Poole, et al., 1998)

'AI… is concerned with intelligent behavior in artifacts.' (Nilsson, 1998)

The table above contains some definitions of AI by Stuart J. Russell and Peter Norvig in their book "Artificial Intelligence: A Modern Approach (2010)" (Refer to the Annex for further details).

Research in AI has focused chiefly on the following components of intelligence: learning, reasoning, problem solving, perception and using language. There are two types of AI, namely data-driven AI through Machine Learning (see below) and knowledge-based AI, based on an explicit representation of domain knowledge that a machine reason about. The current success of AI is mostly due to advances in data-driven AI.

In 1959, Arthur Samuel coined the term *machine learning* only a few years after AI's birth, defining the concept as "the ability to learn without being explicitly programmed". At its core, machine learning is simply a way to achieve AI. It is important to remark that you can get AI without using machine learning, but this would require building millions of lines of codes with complex rules and decision-trees. Refer to the annex for additional definitions.

Deep learning is another widely used term that is also one of the many approaches to machine learning. The long list of further approaches includes decision tree learning, inductive logic programming, clustering, reinforcement learning and Bayesian networks. Deep learning is a specific subfield of machine learning, viz. a new take on learning representations from data that puts an emphasis on learning successive layers of increasingly meaningful representations. In deep learning, these layered representations are (nearly always) learned via models called neural networks structured in literal layers stacked on top of each other. See annex for additional definitions.

AI thrives on data. AI application outcomes become more accurate with more data. AI needs data to build its intelligence (e.g., using machine learning). Given that big data enables AI to reach its full potential, it would be fair to say that there is no data-driven AI without big data. A modern definition of the term big data is: "Datasets whose size is beyond the ability of typical database software tools to capture, store, manage and analyse" (Manyika et al., 2011). Those datasets are a combination of structured and unstructured data, and big data is often said to be characterised by 3 Vs, namely Volume (of data), Variety (of types of data) and Velocity (at which data are or should be processed). Refer to the annex for additional definitions.

Educational data mining and learning analytics are two specific areas in which big data can be used for education:

Data mining: In computer science, data mining is the process of discovering interesting and useful patterns and relationships in large volumes of data. Refer to the annex for additional definitions. Educational Data Mining (EDM) develops methods and applies techniques from statistics, machine learning and data mining to analyse data collected during teaching and learning. EDM tests learning theories and informs on educational practice (US Department of Education, 2012).

Learning analytics: Learning Analytics (LA) is an emerging discipline seeking to improve teaching and learning by critically evaluating raw data and generating patterns to characterise learner habits, predict learner responses and provide timely feedback. Moreover, LA supports decision-making, tailors readable content, simplifies realistic assessments and provides personal supervision of learners' progress. The goal is to scale the real-time LA exploitation by learners, teachers/academics and educational computer-based systems to enhance learners' accomplishments at both course and individual levels. Refer to the annex for references.

Section I:

Leveraging AI towards improving learning and equity

While part of Artificial Intelligence (Clancey, 1987) since its very outset, AI in education has nevertheless faced many difficulties to grow because education systems around the world are more reluctant to technological changes in their traditional organisation. AI was part of the vision promising to transform education by creating tutor systems that could personalise learning. This promise is starting to unfold as present technology has begun experimenting with different models worldwide, bringing many questions to the field of education.

This first section focuses on the ways in which AI could be used to improve learning and equity in education in the developing world. The section addresses two main topics: one dedicated to improving personalisation through AI (pedagogical scale) and the other focused on education management information systems (systemic management scale).

Before discussing real experiences, a brief reference to a key technology that applies to the two main topics in this section: Learning analytics, while still a young field, is a powerful resource for informed decisions and getting better learning results. Learning analytics applies different areas of knowledge such as sociology, psychology, ethics, pedagogy, etc. and can now access the digital revolution to collect a lot of data that can be analysed to extract insights or even develop helpful smart tools for educational or administrative tasks.

Analysing and getting the most out of data is no easy task. For this purpose, advanced data analysis techniques are used, which in turn relay on other disciplines such as statistics-based big data technologies to efficiently handle large data volumes, machine learning algorithms that learn from the data and visualisation tools for efficient communication with people who must ultimately make decisions.

All these software layers for intelligent data processing will allow us to draw insights, detect learning patterns, predict future situations or give recommendations to optimise available resources. Analysis is also a very important step in developing future AI solutions that, with the help of powerful libraries, including yet not limited to natural language recognition, language translation and game theory, will enable us to, for instance, create avatars that simulate the behaviour of a virtual teacher for students or an assistant for teachers. The bright prospects of the future allow us to visualise an AI ecosystem that can help us overcome the different challenges in learning analytics.

Although the future of AI solutions is very promising in the medium term, current solutions are more focused on taking full advantage of data mining/analysis technologies.

The section hereunder provides examples of public policies, philanthropic engagements and private sector initiatives in developing countries as a glimpse into the first stages of implementation of AI-based interventions in education.

(1) AI to promote personalisation and better learning outcomes

In light of the existing initiatives and technologies to come, different studies (Laanpere et al., 2014; Luckin et al., 2016; Mayer-Schönberger & Cukier, 2014; Montebello, 2017) have recently contributed to the ways in which AI can help improve learning opportunities for students and management systems.

Sustainable Development Goal 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. It emphasises equal learning opportunities for all throughout life. AI technologies are used to ensure equitable and inclusive access to education. It provides marginalised people and communities, people with disabilities, refugees, those out of schools, and those living in isolated communities with access to appropriate learning opportunities. For example, telepresence robotics allow students with special needs to attend schools at home or hospital, or maintain continuity of learning in emergencies or crises. In this way, it is able to support inclusion and ubiquitous access.

AI can help advance collaborative learning. One of the most revolutionary aspects of computer-supported collaborative learning is found in situations where learners are not physically in the same location. It provides students variable choices insofar as when and where they wish to study. In respect to computer-supported collaborative learning, online asynchronous discussion groups play a central role. Based on AI techniques such as machine learning and shallow text processing, AI systems are used to monitor asynchronous discussion groups, thus affording teachers with information about learners' discussions and support for guiding learners' engagement and learning.

AI can help personalise learning through various ways. AI can help create a better professional environment for teachers to work more on students with difficulties. Teachers spend plenty of time on routine and administrative tasks such as making assignments and

answering frequently asked questions over and over again in school settings. A dual-teacher model entailing a teacher and a virtual teaching assistant, which can take over the teacher's routine task, frees up teachers' time, enabling them to focus on student guidance and one-to-one communication. Teachers have already started working together with AI assistants for the best outcomes for their learners.

The Computer Assisted Learning (CAL) field creates alternatives to support students´ learning strategies with digital and AI technology (Schittek Janda et al., 2001). AI can help map each student's individual learning plans and trajectories, their strengths and weaknesses, subjects that cost more and are easily assimilated or learned, and learning preferences and activities. Using algorithms to help students navigate through different content paths, AI can personalise learning and improve opportunities for students with the help of their teachers and schools. Intelligent Tutoring Systems are part of the new technological possibilities to expand educational learning in developing countries as shown in recent reviews (Nye, 2015).

Moreover, when considering the tremendous amount of time spent on grading tests and homework, AI as an assessment tool can be applied to learn how a teacher grades and thus free up the teacher's time. AI is not only being used to grade multiple choice tests, but also to assess essays[1].

These opportunities are starting to unfold in developed countries. There is a myriad of applications presently undergoing tests across public and private initiatives alike[2]. This section presents some examples from developing countries to open a discussion regarding the possibilities and risks involved in bringing AI-powered software to personalise learning. We will begin with the case of China, unique in its scope, dimension and level of comprehensive perspective with cutting-edge technology and public-private partnerships, followed by Uruguay, a small developed country that became a bellwether in Latin America. Next, we will present some other state-based, philanthropic and private initiatives in developing countries. These cases have been included as examples to illustrate the state of the art in this field in developing countries and do not aim to be an exhaustive list of every initiative worldwide.

China is a good country to start with, since it is in many ways unique insofar as its size and recent technological development, and also in its recent economic growth (although it remains a developing country in formal definitions). China has 730 million internet users. In 2016, the government launched a plan to become the largest pole of AI development in the world by 2030. China set its national AI strategy for education as part of this technological vision (Jing, 2018).

The state-centred initiative will rely on private pillars. Hujiang, a private digital education company, is developing image and voice recognition software capable of understanding student facial expressions to give AI feedback online. Liulishuo is an adaptive platform that teaches English to 600,000 students at the cost of a single teacher. Master Learner is developing a "Superteacher" capable of answering 500 million simultaneous questions from students preparing for the Gaokao university entrance examination.

In 2016, China's Ministry of Education established that every educational branch of local governments must allocate at least 8% of its budget to the digitisation of education. With 95% of schools connected to the internet, the country is ready for the largest digital education experiment in the world. One of the biggest breakthroughs so far in China is the experimental design to correct essays with AI. The country started to work with 60,000 schools for automatic essay correction with a level of precision matching humans in 92% of the cases. The essay grading machine is based on neural network AI and is improving its ability to understand human language by using deep learning algorithms to plough through essays written by Chinese students and compare notes with human teachers' grading and comments. "It has evolved continuously and become so complex, we no longer know for sure what it was thinking and how it made a judgment," said one of the project researchers (Chen, 2018).

In Latin America, several initiatives have been pushing the introduction of computers in education at a large scale in recent years (Sunkel & Trucco, 2012). **Plan Ceibal** in Uruguay is probably the most advanced state agency

1 For example, in the United States, the Educational Testing Service developed automatic an NLP assessment system to co-grade essays in standardised tests.

2 Refer to the examples presented during Mobile Learning Week 2019: https://en.unesco.org/mlw/2019.

devoted to digital education from the region. One of its main initiatives is an online adaptive learning solution called "Mathematics Adaptive Platform" (PAM for its Spanish acronym). PAM's content has been adapted to the national curriculum and it is a tool that provides personalised feedback according to each student's skill level based on an analysis of student experiences. Some studies have already shown how the program has already had a positive impact on learning (Perera & Aboal, 2018).

PAM was developed by the German company Bettermarks and began to be used in 2013 as part of the One Laptop Per Child program, offering students over 100,000 activities to give personalised assistance to students according to their level of knowledge. PAM provides students with help through a set of over 25 thousand step-by-step exercises and 2800 feedback patterns to explain the solutions of each exercise.

According to Plan Ceibal's official website, the PAM platform offers the following advantages for learning: immediacy of the response; student independence; ease of correction; learning personalisation; classroom gamification; promoting group work; adaptation to the rhythms of class and each student, and a large number of activities.

Some other cases of public endeavours to promote the use of AI in education also come from Latin America[3]. In Brazil, the federal government created **Mec Flix** as a state educational platform. It is a video content platform designed to prepare students for the national higher education examination (ENEM). It has some emergent elements of AI: students have to log in and they can create personalised playlists of video-lessons and get recommendations based on their preferences.

Projects with AI elements in education also come from philanthropic initiatives that work in the developing world. **IBM** is using technology to make an impact on eradicating poverty through the 'Simpler Voice: Overcoming Illiteracy' project. This project uses AI to help adult learners who are illiterate or have low literacy skills, navigate texts with more confidence by translating texts and presenting the basic meaning through visuals or simple spoken word. This will help users overcome difficult obstacles in their day-to-day lives.

Learning Equality is a non-profit initiative that started as an extension of the Kahn Academy to use the contents of the platform in developing countries. Learn Equality launched Kolibri, an open-source educational platform and toolkit designed for low-resource communities.

Other philanthropic international initiatives use prizes as a way to innovate. The $15 million **Global Learning XPRIZE** (XPrize Foundation, 2019) challenges teams from around the world to develop open-source, scalable software that will enable children in developing countries to teach themselves basic reading, writing and arithmetic within 15 months. One of the solutions, RoboTutor (XPrize Foundation, 2019) was developed by Carnegie Mellon specialists to create a learning machine based on AI with robot tutors, voice recognition and data driven algorithms to personalise learning at a large scale.

Finally, many of these "first-generation AI initiatives in education in developing countries" come from the private sector with a lucrative perspective or in partnership with public authorities. In **Brazil**, an EdTech company Geekie – the adaptive learning platform in Brazil accredited by the country's Ministry of Education – is used by over 5,000 schools across the country to provide customised learning experiences for students (WISE, 2011; Rundle, 2015; Rigby, 2016). Through machine learning, the software provides more personalised content as the student uses it more often. It also becomes better at flagging learning difficulties encountered by students, which human educators can then use to determine the necessary interventions.

Daptio is a South African solution that uses deep analytics and provides personalised learning to teachers, students and content creators in Africa and other emerging markets through its online software service. Founded in 2013 and based in Cape Town, Daptio uses artificial intelligence to help students, mentors and teachers to understand the proficiency level of each student and then match the relevant content. Daptio's key local competitors are Get Smarter, Funda and ReThink Education.

M-Shule was launched in **Kenya** in 2016 as a mobile platform filled with lessons based on national curriculum standards delivered via SMS that adapt to each student's skills and abilities using AI technology. As students use the

3 In Guayaquil, Ecuador, the project "**Más Tecnología"** introduced computers for students with a software that personalises curriculums based on the results of assessments in language and mathematics. The project was accompanied by a teacher training plan to implement computer-based lessons three hours per week. A study by the IDB showed that after two years the programme had a positive impact on mathematics test scores (Carrillo, Onofa & Ponce, 2010).

platform, M-Shule tracks and analyses learner performance to empower parents and schools with insights and recommendations.

Some further EdTech initiatives in developing countries also promise to use some elements of AI in education, although they are no strictly AI based, e.g. **SkoolDesk** (Uganda), **Siyavula** (South Africa and Nigeria), **Virtual Learning Africa** and **TopDog** (South Africa), private companies that develop educational content for students of all levels in Africa; and **Zaya Learning Labs** (India).

(2) Data analytics in Education Management Information Systems (EMIS) and the evolution to Learning Management Systems (LMS)

An Education Management Information System (EMIS) is an organised group of information and documentation services that collects, stores, processes, analyses and disseminates information for educational planning and management. It is widely used for education leaders, decision-makers and managers at the regional, local and school levels and for the generation of national statistics. Data-Driven Decision Making (DDDM) applied to student achievement testing data is a central focus of many school and district reform efforts, in part because of federal and state test-based accountability policies. With massive data collected from EMIS, AI algorithms are able to make data-driven decisions to improve school education.

A well-designed and well-functioning EMIS lets members across all levels of the education community access useful information for managing and administering an education system more efficiently, developing feasible and cost-effective plans, formulating responsive policies, and monitoring and evaluating educational outcomes. In countries where data are complete, reliable, regularly collected, and can be aggregated and disaggregated, AI-enhanced EMIS would have a much stronger capacity to automatically analyse the data and generate data dashboards at both the school and national levels. Moving forward, EMIS even opens up a potential for developing predictive decision-making algorithms. While this remains a very nascent area in EMIS development, more countries, both developed and developing, are interested in **transforming their current EMIS** from a school-based aggregated administrative data management system **into an integrated and dynamic learning management systems** that can effectively support real-time decision-making in every aspect of education sector management.

In the **United Arab Emirates (UAE)**, the Ministry of Education rolled out an advanced data analytics platform with over 1,200 schools and over 70 higher education institutions, totalling over 1.2 million students. This data analytics system contains data on curricula, teachers' professional development, learning resources, financing, operations, performance reports, teacher, student and parent feedback, and scores from international assessments like PISA and TIMSS (Leading Countries of the World, 2018). UAE has a data analytics section in its Ministry of Education, dedicated to developing machine learning algorithms in support of strategic studies on the country's education system.

Middle and lower-income countries are also exploring the potential of AI-enhanced EMIS. For instance, **iMlango** is an educational technology program delivered by a partnership of public and private sector organisations in Kenya. Schools measure daily attendance using sQuid's digital attendance system, enabling quick and easy attendance monitoring, real-time data reporting and high reliability and insight into complex student data patterns. Class and school attendances are tracked and reported using advanced analytics, which are then used by teachers and a field team to identify low-attending pupils. sQuid's interactive learning platform delivers learning content in multiple formats for students and teachers. Pupils can access Maths Whizz, the personalised virtual math tutor that tailors the pupils' learning experiences depending on their ability, and other content such as Africa-focused stories, the world's first children's encyclopaedia, and curriculum-aligned revision guides.

While still at a very nascent stage, countries such as **Bhutan** and **Kyrgyzstan** are aspiring to create integrated education information management systems based on individual student tracking that can allow for personalised learning support, and efficient and effective school and sector management. This opens the possibilities of introducing AI-enhanced learning analytics in their systems in the near future.

The school mapping initiative **UNICEF Innovation** is exploring the potential of Deep Learning (DL) algorithms in collaboration with academic institutions and private companies. Their studies show that DL algorithms are useful for example to recognise schools in satellite imagery, thus rendering unmapped schools visible.

AI has begun unveiling its potential in research for sustainable development. The contest "**New debates.**

Data for development" organised by the Inter-American Development Bank financed the study "Big Data for public policy in education: the Chilean case". In this study, Chilean researchers used open data published by the government regarding social, geographical and educational contexts. The study was able to predict student dropout by localising the geographical distances from houses to schools. Using 127 characteristics of students and their geographical locations, researchers created an algorithm to develop a "geography of educational opportunities", with a detailed map of schools, access, academic results and dropout predictions.

Section II:

Preparing learners to thrive in the future with AI

Businesses are generally quick to adopt AI-based solutions. This means an increasing demand for new types of jobs and skills that are linked to the use of AI in industry. As such, there is strong imperative for the education sector to respond in that curricula must be reworked and policies reformulated. However, no country in the world is genuinely ready for intelligent automation; not even those traditionally conceived as leaders in the field as policy response to intelligent automation remains nascent (The Economist Intelligence Unit, 2018). Nevertheless, there is exemplary work being done by countries across the world to ensure that their education systems are promoting the acquisition of competencies required by an AI-powered society. Their efforts can serve as starting points towards the development of a concerted policy framework for education's response to AI.

(1) A new curriculum for a digital and AI-powered world

Education plays a critical role in efforts to make future workforces AI-ready. Bridging the AI skills gap goes beyond the adoption of increasingly powerful technologies to facilitate learning. It also means rethinking the content and methods used to deliver instruction at all levels of education. The curricular reform efforts cited in this paper show a clear need to define 'AI competencies' beyond basic ICT competencies, which is how many countries defined them when incorporating 21st century skills in their respective educational programs, towards skills that would allow learners to identify and solve problems using computing techniques, methods and technologies.

In the context of a near future society empowered by AI, it is important to develop new skills to create and decode digital technologies. To approach this topic, we will focus on new frameworks that characterise digital skills for students and teachers and some cases from different countries. The objective is to reveal the power of digital competencies that can analyse, use and decode Artificial Intelligence as a powerful technology, to which we must necessarily think in a context to understand its scope, limitations, potential and challenges.

Digital competencies frameworks

The need to collect data for the SDG 4 Education indicators sets the table for a collective work of developing a Global Framework to Measure Digital Literacy. This has been the priority of a task force of experts and country representatives established by the Global Alliance to Monitor Learning (GAML) and chaired by the GEM Report. The main definition of digital literacy is: "the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital devices and networked technologies for participation in economic and social life. It includes competencies that are variously referred to as computer literacy, ICT literacy, information literacy, and media literacy" (Antoninis & Montoya, 2018). The following table shows the set of competencies defined as part of this framework.

As a parallel initiative, the Information and Communication Technologies Competency Framework for Teachers (ICT-CFT) was developed by UNESCO (2011) in consultation with major private actors such as ISTE, Cisco, Intel and Microsoft, and has been regularly updated since. The framework was updated in 2018.[4] This framework specifies the competencies that teachers need to integrate in their professional practices to develop critical knowledge and awareness with their students in the digital era.

The framework emphasises the role that digital technologies have in supporting six key areas of knowledge: 1-Understanding ICT in education; 2-Curriculum & Assessment; 3-Pedagogy; 4-ICT; 5-Organisation & Administration; 6-Teacher Professional Learning. The framework sets three phases of knowledge acquisition: 1-technology literacy; 2-knowledge deepening; 3-knowledge creation.

This framework underlines that it´s not enough for teachers to have certain skills to manage digital technologies and to teach them to their students, but also that teachers must help their students be capable of collaborating, solving problems and being creative in the use of digital technologies. In a growing technological world, these skills become part of their citizenship training to participate in the digital society where they will live.

Another framework along this same line of support to teachers in the integration of digital technologies to their practices is "ICT Competencies and Standards from the Pedagogical Dimension", developed by UNESCO Santiago and the Universidad Javeriana (2016).

This framework was created to contribute in the vision of teacher training to face the challenge of teaching in

4 The corresponding publication can be accessed via this link: https://unesdoc.unesco.org/ark:/48223/pf0000213475

Table 1: Proposed digital literacy competency areas and competencies

Competency area	Competencies
0. Fundamentals of hardware and software	0.1 Basic knowledge of hardware such as turning on/off and charging, locking devices 0.2 Basic knowledge of software such as user account and password management, login and how to do privacy settings, etc.
1. Information and data literacy	1.1 Browsing, searching and filtering data, information and digital content 1.2 Evaluating data, information and digital content 1.3 Managing data, information and digital content
2. Communication and collaboration	2.1 Interacting through digital technologies 2.2 Sharing through digital technologies 2.3 Engaging in citizenship through digital technologies 2.4 Collaborating through digital technologies 2.5 Netiquette 2.6 Managing digital identity
3. Digital content creation	3.1 Developing digital content 3.2 Integrating and re-elaborating digital content 3.3 Copyright and licenses 3.4 Programming
4. Safety	4.1 Protecting devices 4.2 Protecting personal data and privacy 4.3 Protecting health and well-being 4.4 Protecting the environment
5. Problem solving	5.1 Solving technical problems 5.2 Identifying needs and technological responses 5.3 Creatively using digital technologies 5.4 Identifying digital competency gaps 5.5 Computational thinking
6. Career-related competencies	6. Career-related competencies refers to the knowledge and skills required to operate specialised hardware/software for a particular field such as engineering design software and hardware tools, or the use of learning management systems to deliver fully online or blended courses.

Source: A Global Framework for Reference on Digital Literacy Skills for Indicator 4.4.2 (UIS, 2018a)

an information and knowledge society. This aims to be a benchmark in training for the improvement of educational quality in educational institutions at any level of training base on an approach of levels of appropriation of ICT and its educational uses. This framework describes the contextual elements where the proposal is framed. The ICT Competencies and Standards model is presented from the pedagogical dimension based on levels of appropriation of ICT, its meaning and use from the training route.

The relevance of this proposal is its constitution as a guiding base for any teacher and educational institution facing the appropriation of ICT in their practices and educational strategies. The educational institution or the teacher in particular can evaluate their practices and educational strategies with use of ICT regarding the expected standards and, from this process of identification and recognition, continue with a process of training, support and evaluation based on their level of ICT appropriation.

Finally, another framework is **DigComp** (Joint Research Centre, 2018), designed by the European Union to support the development of digital skills of individuals.[5] The framework describes what competencies are needed today to use digital technologies in a critical, reliable, collaborative and creative way, so that individuals can achieve their goals related to work, learning, leisure, inclusion and participation in the digital society.

This framework is structured in five competency areas that describe the key components of digital competencies, namely Information and data literacy; Communication and collaboration; Digital content creation; Safety; and Problem solving. The framework takes these dimensions and maps them through four proficiency levels: foundation, intermediate, advanced, highly specialised.

Computational thinking

Computational Thinking (CT) has emerged as one of the key competencies to enable learners to thrive in an AI-powered society. There is clear acknowledgement of the importance of CT skills: The countries examined in this paper have either laid out plans to incorporate CT in their educational curricula or have already done so. The Computer Science Teachers Association (USA) defines CT as a problem-solving process possessing the following characteristics (International Society for Technology in Education and Computer Science Teachers Association, 2011):

- Formulating problems in a way that enables us to use a computer and other tools to help solve them;
- Logically organising and analysing data;
- Representing data through abstractions such as models and simulations;
- Automating solutions through algorithmic thinking (a series of ordered steps);
- Identifying, analysing and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources; and
- Generalising and transferring this problem-solving process to a wide variety of problems.

While distinctly belonging to the domain of computer science, CT is therefore a competency that finds applications in other disciplines. Given the increasing presence of AI in the workplace, CT becomes a critical competency if learners are to cope with changing labour market demands. Many countries have thus begun incorporating CT in their respective educational curricula.

A survey conducted by the European Commission shows that while **European Union (EU)** Member States are at different stages of integrating CT in their respective educational curricula, each one has begun working on it (European Commission, 2016). The survey found three clusters in terms of the level of CT integration in curricula:

1. countries that have started a curriculum review and redevelopment over the past three to five years such as the United Kingdom, France, Italy, Portugal and Finland
2. countries that are planning to introduce CT into their curricula such as Greece, Sweden, Norway and the Czech Republic; and
3. countries that have a longstanding tradition of computer science education, particularly in secondary school such as Austria, Poland and Lithuania.
4. In other words, there is universal recognition across the EU of the importance of integrating CT in educational programs.

In the **United Kingdom (UK)**, for instance, the Royal Society published a report in 2012 that described the

5 See also https://schools-go-digital.jrc.ec.europa.eu/.

shortcomings of computing instruction in the country. This report described how instruction on ICT at the time merely aimed for students to acquire basic digital literacy skills, i.e. the general ability to use computers, and recommended a curricular shift towards information technology, computer science, programming and computing (The Royal Society, 2012). The Royal Society argued for the importance of CT and its applications to natural and artificial systems. They posited that CT skills were also useful and applicable to domains outside computer science (The Royal Society, 2012). Based on the findings of this report, the UK redesigned and implemented a new computing curriculum in 2014, whose aims were more oriented towards fostering an understanding of fundamental principles and concepts in computer science and their applications, and the ability to analyze problems in computational terms and to create computer programs that would solve those problems (UK Department for Education, 2013). Instruction proceeds along four key stages, spanning preschool, primary school, lower secondary school and upper secondary school, with well-defined target competencies for each stage (Yadav, 2016). Computer science and computing instructors are able to share ideas and resources through communities of practice like "Computing at School", an affiliate organisation of the British Computer Society, the Chartered Institute for IT (Heintz, Mannila & Färnqvist, 2016).

Estonia launched a similar initiative in 2012 called the "ProgeTiger Programme", which aims to introduce programming and robotics in educational curricula (HITSA, n/d), spanning pre-school, primary and vocational education (HITSA, n/d). This programme is managed by the Education Information Technology Foundation (*Hariduse Infotehnoloogia Sihtasutuse*, HITSA), which is in turn funded by the Estonian Ministry of Education and Research. The Government of Estonia set HITSA's objective of "[ensuring] that sufficient age-appropriate digital competency necessary for further studies and to succeed in society is acquired at all levels of education by integrating the use of digital solutions into the entire process of teaching and learning" (HITSA, 2015). The ProgeTiger Programme approach has three axes, two of which directly relate to the development of AI-related competencies: Engineering Sciences, encompassing programming, robotics and electronics; and Information and Communications Technology, encompassing computer science and digital communications (HITSA, 2015).

The push to integrate CT in educational curricula from as early as preschool is not exclusive to Europe.

Argentina's Ministry of Education, for instance, recently announced a plan called 'Aprender Conectados', which aims to incorporate digital learning across all levels of compulsory education. One component of this plan is to integrate programming and robotics in the country's educational program, beginning from preschool all the way to secondary school, in all schools by 2019. The learning curriculum prescribes specific, age-appropriate learning competencies at each level of education, from preschool to secondary school, building towards full competency in using computing methods and techniques, individually and collaboratively, to solve problems (Ministerio de Educación, 2017).

Singapore also starts young in its effort to develop CT competencies amongst learners. In 2016, the country's Info-communications Media Development Authority (IMDA) launched the PlayMaker Programme, which introduced robots to 160 preschool centres to develop very young learners' appetite for and competency in robotics, programming and computer science through play (Graham, 2018). A mid-test and post-test study involving a sample of preschool children using KIBO – one of the robotics kits used in the PlayMaker Programme – showed high success in developing foundational programming concepts among children in the sample group (Sullivan & Bers, 2017). The PlayMaker Programme is part of a broader movement, called CODE@SG, to integrate coding and CT in Singapore's formal education system through Infocomm clubs, student competitions, enrichment programmes and gamified approaches to learning (Infocomm Media Development Authority, 2017). This initiative aims to build a "Smart Nation for the future", whose citizens are "familiar with tech skills and … also sensitive to how tech can be applied to improve living", acknowledging that CT is "[becoming] an increasingly essential part of our lives and careers" (Infocomm Media Development Authority, 2017).

Malaysia has also embedded CT in its educational programme. During the launch of Malaysia's *#mydigitalmaker* movement in 2016, Malaysia Digital Economy Corporation (MDEC) CEO Yasmin Mahmood emphasised that the integration of CT in educational curricula meant "embedding thinking skills – not IT skills – […] to then apply to problem-solving" (Singh, 2016). The #mydigitalmaker Movement is a partnership 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). In 2018, 22 schools in Malaysia have been selected as #mydigitalmaker Champion Schools, i.e. schools funded by MDEC to implement the #mydigitalmaker framework, including the establishment of a Digital Maker Hub, which is a key feature of the #mydigitalmaker Movement (My Digital Maker, 2018). A Digital Maker Hub functions like a workshop or laboratory with a structured learning programme, whereby students have access to various tools to create and collaborate on tech projects (Ministry of Education & Malaysia Digital Economy Corporation, 2017). All Digital Maker Hubs contain a 'creative lab' where students can convert their ideas into code in any programming language, and a prototyping studio, where they can test and see their products at work.

It must be noted, though, that the examples provided are only illustrative and are in no way exhaustive. The incorporation of CT in educational curricula is a reform that pervades across several countries and regions worldwide. This shows a clear shift from basic digital literacy to higher-order (computational) thinking skills. While the push to integrate 'ICT competencies' into educational curricula has long existed, particularly since the movement towards 21st century skills, 'ICT competencies' were defined so broadly that their incorporation into educational curricula across countries ranged from basic digital literacy to algorithmic skills. The increasing presence of AI in all aspects of human activity clearly conveys a need to operationalise 'ICT competencies' as being more than digital literacy, in which regard CT becomes critical.

Beginning CT-related instruction from early education is a common thread across these countries. The acquisition of CT skills thus becomes a cumulative process with well-defined target competencies for learners as they progress through a ladder of proficiency levels. These proficiency levels need not necessarily have to be associated with specific grade levels such as the case with Estonia, since educators may simply use proficiency levels as a framework to identify learners' individual progress in acquiring CT skills and subsequently provide individual interventions as needed, regardless of a learner's formal grade level.

(2) Strengthening AI capacities through post-basic education and training

The number of countries that have developed a national AI strategy is increasing. France in Europe, China in Asia and lately the United States in North America are examples of the kind of comprehensive strategies that, despite a huge focus on R&D, assign a major role to the development of an AI-capable workforce. In all these three cases, most attention is given to higher education, because of its obvious links with R&D, but also to technical and vocational education. Yet Finland has chosen a different pathway by creating a national platform to rapidly achieve the goal of 1% of the total population being AI-literate.

Higher education

The pressing need to adapt to rapid developments in AI exerts itself on post-compulsory educational institutions as well. Building AI expertise through higher education and research is one of the main approaches used by governments to address their respective skill gaps. In an effort to boost their respective capacities in AI and become leaders in the field, many countries are seeking to make professions in AI research and practice more attractive.

France, for example, published a report that laid out a strategic framework for AI domestically and in Europe. Research and human resource development are key components of this strategy, with France envisioning, among others:

- the creation of research laboratories to study how AI transforms the workplace;
- increased incentives for AI researchers to attract both domestic and international talent; and
- the development of AI programmes at the bachelor's, master's and doctoral levels, as well as in technical and vocational education and training (TVET) (Villani, 2018).

The country also aims to build more academia-industry collaborations and forge more partnerships between universities and other research institutes, in effect creating a university network for AI studies. Towards this end, French President Emmanuel Macron committed €1.5 billion, which will be managed by the *Institut National de Recherche en Informatique et en Automatique* (Campus France, 2018).

South Korea also published a master plan to prepare the country for what it calls the 'Fourth Industrial Revolution'. Education forms an important part of this master plan: The Government of the Republic of Korea aims to produce 5,000 new graduates trained in AI every year, beginning in 2020, thus adding 50,000 new AI specialists to its talent pool by 2030 (Government of the Republic of Korea, 2016). Moreover, the country also intends to provide 10-year support to 'topnotch graduate-schools-turned-research-centres to lead the development of intelligent IT, including AI' through Research Innovation Grants,

resource provision and subsidies for hiring scholars and professors internationally. The government has committed around 4.3 million USD to fund this research initiative (Sharma, 2018). Furthermore, the country aims to allocate 2 billion USD towards the establishment of six new AI graduate institutions, the strengthening of academia-industry partnerships and the creation of 4,500 domestic scholarships for AI students (Sharma, 2018).

China has also developed a *Next Generation Artificial Intelligence Plan*, which was launched in 2017. This plan sets out a vision for the country to be the world's centre of AI innovation by 2030 (Government of the People's Republic of China, 2017). Education and training play a huge part in the realisation of this plan, with the government aiming to accelerate the cultivation of top-tier talent in the field of AI (Government of the People's Republic of China, 2017). The government intends to achieve this by developing AI majors in university, increasing enrolment in master's and doctorate programmes in AI, and integrating AI content in the study of other disciplines such as mathematics, biology, psychology, sociology and law, among others (Government of the People's Republic of China, 2017). In line with the objectives of this plan, the country launched an International AI Training Programme for Chinese Universities, which began operating at Peking University in 2018 (China Daily, 2018). Through this programme, China aims to train at least 500 teachers and 5,000 students in AI in the country's top universities over the next five years (China Daily, 2018). The government has also invested in vocational training with the Ministry of Education collaborating with three robotics enterprises to co-establish 10 public vocational training hubs and 90 vocational training centres within Chinese vocational schools by 2020 (He, 2017). Towards this end, the Ministry of Education has allocated 5 million RMB (≈726,427 USD) to each training hub and 3 million RMB (≈435,856 USD) to each training centre, as well as supplementary resources for training teachers and procuring equipment (He, 2017).

Technical and Vocational Education and Training (TVET)

TVET institutions should also be capable of offering programmes that incorporate AI-related competencies, especially if they intend to produce graduates whose skills are attuned to changes in the labour market. In some countries, lifelong learning is understood as referring to basic skills education and adult literacy programmes (Chakroun & Daelman, 2018). However, while lifelong learning certainly includes these aforesaid initiatives, it encompasses a broader spectrum. The International Labour Organisation (ILO) defines lifelong learning as including "all learning activities undertaken throughout life for the development of competencies and qualifications" (ILO, 2004). The ILO argues that "the renewed interest in lifelong learning is partly due to the interest by industry which considers lifelong learning as the appropriate skill formation strategy for the 'new economy" (ILO, 2004).

Germany and **Singapore** have similar individual training account schemes. In the former, eligible individuals, either unemployed or employed workers in specific circumstances, can receive education vouchers from their respective employment agency or job centre to pursue relevant training; these vouchers are redeemed at educational institutions that have been accredited to provide continued training and education (Federal Ministry of Labour and Social Affairs, 2012). Similarly, the latter launched its SkillsFuture initiative in 2016 to provide 500 SGD worth of credits (topped up periodically) to every citizen aged 25 and up to pay for courses at any of the 500 government-sponsored training providers (Skills Future, n/d). Data analytics is one of eight training streams that Singaporeans can follow.

The UNESCO Education Sector is also developing initiatives that harness AI to achieve SDG 4, with a particular focus on TVET. For instance, in partnership with Ericsson, UNESCO's ICT in Education Unit is launching the initiative 'Artificial Intelligence for Youth' that focuses on scaling up AI skill development for young people. This project aims to support and foster the capacities of master trainers to empower youth in developing innovative AI applications. It will also create a repository of curated AI-related training courses, and mobilise AI hub centres and hackathons to cascade training for youth across a broader scale.

The examples herein emphasise the importance of collaborating with industry in bolstering the effectiveness of TVET when it comes to filling in AI competency gaps. Constant coordination with industry is needed to ensure that the instructional content of TVET programmes are aligned with the needs of the labour market. Since AI technologies evolve very quickly, this coordination must be regular and systematic; it should not be surprising that instructional programmes might need to be constantly rethought and revisited, given the rapid pace of development in AI technologies.

However, coordination is not the only way by which TVET institutions can collaborate with industry. Ministries of education and labour can partner with industry players to share the training 'burden' of bridging the AI skills gap. Since industry stands to benefit from a larger AI-capable talent pool, it should also invest in training and upskilling, recognising that bridging the AI skills gap is not the education sector's sole responsibility.

Governments indeed recognise the important role of TVET in bridging the AI skills gap, with some even installing welfare mechanisms to support the upskilling and retooling of individuals holding jobs that are vulnerable to automation such as the cases of Singapore and Germany. However, bridging the AI skills gap should not be confined to reforms in formal education.

Non-formal and informal learning

'Schooling' must be distinguished from 'learning': While schooling happens within structured learning environments contained within a fixed time and place, learning occurs in a continual fashion, regardless of time and place. With the existence of mobile technologies, for instance, it has even become more apparent that learning can occur well outside the bounds of traditional, brick-and-mortar educational institutions (Woolf et al., 2013). **Massively open online courses (MOOCs)** and online learning platforms such as **Khan Academy** are alternative channels by which individuals can access training on AI-related skills, with various universities offering online courses on programming, data science and machine learning, for instance. There have also been grassroots initiatives such as *Code.org* and *EU Code Week*, whose outreach only continues to grow over time (European Commission, 2016).

MOOC platforms are in fact good examples of learning systems that contribute to bringing training on AI-related skills and use AI techniques to make the most of themselves. This is because of their inherent digital character. Coursera, edX, iversity, Future Learn, Udacity, CognitiveClass.ai, etc. are examples of such platforms which, in some cases, say that they are applying NLP (Natural Language Processing) and Machine Learning in combination with Crowdsourcing, for example, to grade short answers, coding exercises, vocabulary and even automatically generate 'wh' (who/what/when/where/why) questions.

The impact of these kind of platforms lies in the virtuous circle that they can generate among four factors: (i) Global Reach, which produces a big amount of usage data as they reach the whole World, (ii) they can combine Synchronous and Asynchronous learning, which means flexibility for students, (iii) they offer an opportunity for "career changers" for lifelong learners, and (iv) they let the owners and teachers research and experiment.

It must be noted, though, that given the relatively recent appearance of these informal learning platforms, data and research on their overall effectiveness still have a long way to go insofar as they must be well measured and contrasted. When it comes to measuring the effectiveness of these platforms, in fact for any learning system at scale, the definition of relevant key performance indicators is of course a very complex task. It is easy to start using simple indicators like participation, persistence, completion, satisfaction and activity. But more sophisticated metrics should arise, ranging from correlations between different measures of activity to non-trivial successful/unsuccessful patterns that can be discovered using the power of AI.

MOOCs may be considered to fall within a wider category of "Large-scale Learning Environments". Apart from the examples of formal MOOC platforms given above, other less formal systems, usually based on communities, have a relevant impact in how many people learn: citizen science communities, YouTube channels by volunteer teachers, collaborative programming communities (Scratch, GitHub), community tutorial and forums systems (StackOverflow), shared critique communities (DeviantArt), informal communities of learners ("Explain It Like I'm Five" sub-Reddit), etc.

It remains important to invest in such non-formal and information learning programmes. The aforementioned case of the national Finnish strategy to make 1% of the total population AI literate provides a good example of how informal and non-formal capacity development initiatives can also be fostered through ICT-based platforms. Given the rapid pace at which AI technologies are evolving, constant and continuous upskilling will always be needed. Moving forward, however, when there is more data available regarding the results of these lifelong learning initiatives, governments can begin to monitor and evaluate and therefore make the necessary adjustments to render those initiatives more effective.

Section III:

AI in education - challenges and policy implications

AI-powered services have already become prevalent in human lives in many places, including the least developed countries. For instance, bots in **Kenya** now give answers to questions about reproductive health in a safe and confidential way, thus dispensing with a visit to the doctor's office. The bots rely on AI technology to process and reply to questions concerning sexual and reproductive health securely and confidentially. Several AI applications have also emerged in the agriculture sector across several African countries. In **Kenya**, Vital Signs collects and integrates data on Agriculture, Ecosystems and Human Well-Being. It uses satellite imagery data to estimate rainfall and drought patterns. In **Nigeria**, Zenvus is a data-driven platform that provides farmers with insights based on data collected from sensors and other means. Their mission is to eliminate poverty in developing countries by improving overall farming productivity.

Financial and public transportation sectors are further examples of where AI-powered technologies are changing people's lives. Tala is Kenya's number one finance application. It provides credit with low fees and easy repayment schedules. Their target customers have no credit history. Through the application, the company can assess excluded customers by analysing Facebook and SMS data to determine the customer's risk of failure to pay. Another example in **Nigeria** is Kudi.ai, a system that lets users improve the use of money transfers by using natural languages and AI to make peer-to-peer payments easier using a chatbot that works on popular messaging apps.

These examples prove that radical innovation is possible under extreme conditions. Some authors have developed a framework to analyse frugal innovations as solutions conceived through needs under difficult conditions (Leadbeater & Wong, 2010). New discussions both in the field of international aid and within national policies are starting to unfold. Is education a field in which technology can help leapfrog inequalities (Winthrop, Barton & McGivney, 2018)? How can developing countries with severe social problems address the complex ecosystem needed to develop AI solutions in education? How can public policies empower teachers so they are key actors in this process and not mere spectators?

Recent systematic reviews show that AI in Education has been a field of research concentrated in developed countries (Roll & Wylie, 2016). As part of an advance technological discussion that builds upon firmly developed infrastructure and knowledge ecosystems, AI in Education is a neglected topic in the developing world. This document intends to bring the discussion to the least developed and developing countries, recognising the multiple limitations these countries face while uncovering the need for structural innovation to leapfrog education as a human right using technological opportunities to advance at a large scale in new learning scenarios.

This final section presents the six main future challenges regarding the incorporation of AI in education as a way to improve the equity and quality of learning and to promote the realisation of SDG 4. It combines the two main topics of this document, namely the new opportunities of AI to improve learning and the way education should prepare students and future workers in an AI-powered world.

First challenge: a comprehensive public policy on AI for sustainable development

The education sector is both customer and actor in the face of sweeping developments in AI-powered technology. In this regard, the education component becomes key when countries develop national AI strategies, as we've seen in the cases of Australia, China, Estonia, France, Singapore, South Korea and, albeit more recently, the United States.

On one hand, AI holds great potential for improving education systems: How can AI help learners, teachers, administrators and policymakers? On the other hand, education systems are expected to form learners who possess the skills needed to thrive in a society surrounded by AI. Currently, most of the AI developments in education come from the private sector. Companies such as Pearson, McGraw-Hill, IBM, Knewton, Cerego, Smart Parrow, Dreambox, LightSide or Coursera are advancing in the introduction of adaptive learning through intelligent algorithms that use Big Data to personalise learning. Most governments are struggling to manage this serge in private sector engagement with AI in education.

Recent studies show that the digital education market will increase 5% annually until 2021 (Docebo, 2016). Experts forecast a 50% growth in the artificial intelligence market between 2017 and 2021 (HTF Market Intelligence, 2018). What is the role of the state in this context? Can it cope with the velocity of technological change driven by private markets?

The best way to approach these initial questions for developing countries is through a comprehensive perspective on the topic. AI works within complex ecosystems of knowledge, innovation, business and new regulations. State policies should be capable of simultaneously addressing multiple questions to generate solutions and regulations, and create or support innovation ecosystems to bring the opportunities of AI to the field of education.

The development of public policies regarding AI in education is still in its infancy, but it is a field that will most likely grow exponentially in the next ten years. It is difficult to find some common components at such an early stage, but some issues are starting to emerge as key factors shown by the study cases:

- Public policies will not be able to cope with the speed of innovation in the field of AI with its traditional institutions. New agencies and institutions within the public sector are key to creating the AI intellectual and material context of sustainable development.
- As part of this strategy, countries are developing labs and incubators with public funds to unfold initiatives in AI that promote public goods.
- The state must create partnerships with the private sector to enlarge the AI ecosystem because the public sector will not be able to innovate at such a complex technological level alone.
- To address ethical issues, it´s essential to consult experts and form teams to create blueprints and roadmaps in the uncertainty of the near future development of AI.
- As part of the ecosystem, it´s essential to create new funding opportunities to develop academic and research facilities for the formation and training of AI specialists.
- The initiatives from these countries are unleashing the potential of AI in education with experiments of adaptive learning platforms, online assessments, automatic essay correction, specially design in context of large-scale technological penetration.
- Some of these countries are also concerned with the ethical consequences of AI in education. Therefore, new regulations are being introduced to secure the use of AI by private companies in terms of data uses, privacy and the transparency of the ways in which algorithms are designed.
- As part of the commitment to develop a complex ecosystem of AI as a common good, some governments are starting to enlarge the public understanding and public debate regarding these issues within the context of a new democratic ideal.

As presented in this paper, many countries have programmed significant budgetary commitments towards the creation of AI research centres and the recruitment and training of AI professionals. Indeed, strengthening AI training and research through higher education is seen as critical for building national expertise in AI. Governments are investing in research and advanced training in AI, which primarily occur at higher education institutions, through the establishment of academic centres of excellence in AI, university and research institute networks and scholarships to attract more talent into the field of AI.

Public-private partnership is another important aspect of strengthening AI training and research. Countries cited in this paper have forged partnerships between industry and academia not only to share material and financial resources but also to ensure that educational programmes are well-aligned with labour market needs. Partnerships should not be limited to industry and academia, though; intra-sector partnerships prove just as important as academia-industry partnerships. Partnerships between universities and research institutes foster collaborative research, which can accelerate the development of expertise in AI.

For these efforts to be effective, however, they must be aligned with a broader national strategy for AI, with a clear vision and clearly defined objectives. This is the case for all three examples described above. The elaboration of such strategies can be seen as anticipatory responses to AI: Rather than passively responding to developments in AI, the cited countries have chosen to build national expertise so they can lead the development and dialogue in this regard. An effective education sector response to AI should not be merely 'palliative'. The education sector is well-placed to shape a country's vision for AI since it is, after all, the cradle of future expertise in the field.

At this point, we promote the creation of an AI Observatory to look at relevant initiatives of AI in education and inform on national and international AI strategy plans (see Conclusions).

To understand the potential of these initiatives and the situation of other countries, attention needs be shifted towards benchmarking parameters. This will allow initiatives to compare themselves and identify where they

stand in the journey. This could even allow countries to compare themselves on becoming AI ready. For instance, the Automation Readiness Index: Who is ready for the coming wave of automation? Government AI Readiness (Stirling, Miller & Martinho-Truswell, n/d).

With this comprehensive view in mind, what are the possibilities for introducing AI in education in developing countries? Technology has open new opportunities for countries facing large social challenges. In Africa, access to mobile phones has grown exponentially in the last 15 years, driving economic growth (Aker & Mbiti, 2010). New discussions are emerging in developing countries to use the power of AI to promote social equality (BID, 2018).

Second challenge: Ensuring inclusion and equity in AI in education

While AI can open numerous possibilities as presented in this paper, it can also be a disruptive technology and may deepen the existing inequalities and divides as the marginalised and disadvantaged population are more likely to be excluded from AI-powered education. The result is a new kind of digital divide: a divide in the use of data-based knowledge to inform intelligent decision-making (Hilbert, 2015).

Equity and inclusion should be core values when designing policies for AI in education. Policy makers should thus ask several inclusion and equity questions when developing their policies. For instance, what infrastructure conditions are urgent in developing countries to make AI in education possible? What have we learned from previous experiences to build sustainable and equitable conditions to digital rights in terms of internet access? How can AI serve the education provided to disadvantaged groups and populations? How can digital education and AI grow faster in developing countries to close the educational gap between rich and poor students of the world? What are the good practices on AI for women and girls to close gender gaps?

Recent studies have mapped the obstacles for introducing AI in education in developing countries. The main ones include 1-ICT hardware availability, 2-Electrical availability, 3-Internet reliability, 4-Data costs, 5-Students´basic ICT skills, 6-Language and 7-Lack of culturally appropriate content (Nye, 2015). Further reviews on the introduction of Big Data in developing countries show that the lack of basic infrastructures creates a new digital divide in the use of data-based knowledge for informed intelligent decision-making (Hilbert, 2015). To remove these obstacles, multiple policies must be put in place. It is essential to start by defining the internet as a human right and creating multiple international alliances to build infrastructure in the poorest sectors of the developing world (Mutoni, 2017). The work carried out by the United Nations Broadband Commission is one clear example of this.

Third challenge: Preparing teachers for AI-powered education and preparing AI to understand education

There are no indications of a system-wide adoption of AI-based applications for teaching and learning or system management, even though the educational technology industry has yet to cease production on new developments. Their fundamental flaw is that, rather than addressing the existing problems and issues that teachers face, they promote new ways of organising teaching that collide with mainstream traditional practices, often without rigorous evaluations supporting the claimed benefits of new solutions. Not surprisingly, teachers hear what vendors have to say, but do not necessarily buy into it. Against this context, some countries have already designed policies that support the national EdTech industry's efforts to promote innovation, intensify efforts and modalities of qualifying and empowering the demand (teachers and schools), while supporting their innovative practices and, finally, exploring how AI can contribute to a richer, more evidence-informed policy and planning environment in education.

The examples presented herein show how learning analytics platforms can use predictive algorithms to help teachers diagnose and anticipate learning difficulties faced by learners and thus implement personalised interventions to respond to those difficulties. However, while predictive algorithms certainly facilitate data analysis and interpretation, these algorithms are not what make learning analytics systems powerful. The effectiveness of learning analytics systems lies in their usefulness and relevance to learners and educators. Real-time data processing should translate into real-time feedback, quicker intervention and individualised instruction. As such, educators continue to play the primary role. Teachers and head teachers should be given sufficient autonomy to manage their respective classrooms and schools, founded on the notion that they are most familiar with the needs of their learners. Automated analyses only serve that

autonomy if teachers and head teachers are empowered to manage learning provision in their respective schools. If not, the implementation of any AI-powered tool can only do so much.

Teachers will therefore remain at the frontline of education; it is misinformed to say that AI can replace teachers. Arguments to the contrary reduce the teaching profession to the performance of solely cognitive and routine tasks, ignore the research that stresses the importance of a human mentor to support the learning process and neglect the creative and socio-emotional aspects of teaching, which go beyond mere knowledge transmission (Bali, 2017). Furthermore, teachers will decide how and when it would be appropriate to use AI-enabled tools. As such, the development of these AI-enabled tools and their integration into the delivery of educational programmes must be a participatory process, designed to "deliver the support that educators need – not the support that technologists or designers *think* they need" (Luckin et al., 2016). That said, AI-enabled technologies do provide opportunities to automate certain routine and administrative tasks such as grading and recordkeeping, which teachers are currently performing. Automating such tasks can free up teachers' time, effectively allowing teachers to devote more energy to the creative, empathetic and inspirational aspects of their profession.

Given the eventual widespread use of AI in the classroom, teacher training is therefore a critical aspect of empowering teachers to use educational data to improve pedagogy. To be able to use AI-enabled technologies effectively, teachers would also need assimilate new competencies, specifically (Luckin et al., 2016):

- A clear understanding of how AI-enabled systems can facilitate learning provision, so that they can make sound value judgments on new AI-enabled educational products;
- Research and data analytical skills, so that they can interpret data provided by AI-enabled systems, ask useful questions about the data and provide students with feedback based on insights that arise from the data; and
- New management skills, so that they can effectively manage both human and AI resources at their disposal.
- A critical perspective on the ways Ai and digital technologies affect human lives and new frameworks of computational thinking and digital skills can increment students´ capacities to understand the power, the dangers and the possibilities of AI.
- Enable teachers to take advantage of AI taking over repetitive tasks to bring in more human capabilities they may not have had time for before: mentorship, emotional support, interpersonal skills, etc.
- Help learners acquire those skills and competencies that are likely not to be replaced by machines.

Teacher training programmes should therefore account for these new competencies, both at the in-service and pre-service level.

Not only teachers have to prepare to understand and grasp the new technological possibilities digital and AI-powered education are developing. The history of innovations in education is full of lost promises that fail to understand how teachers work and the culture of schools. To create new educational possibilities, AI developers have to participate in a new dialogues with educators, content designers and cross-disciplinary specialists.

At present, two distinct communities have evolved, namely learning analytics (LA) and Educational Data Mining (EDM). These two communities significantly overlap in terms of objectives and techniques, but they differ in that EDM researchers, originating from the community of intelligent tutoring systems, work on very small-scale cognition. EDM methods are drawn from a variety of disciplines, including data mining, machine learning, psychometrics of statistics, information visualisation and computational modelling. The field of learning analytics is more focused on learning content management systems and large-scale test results. To do so, they combine institutional data, statistical analysis and predictive modelling to identify which learners need help and how instructors can change academic behaviour.

Future developments in AI-powered software in education must build strong bridges between cognition, classrooms and large-scale test scores. The challenge is to create new pedagogical dialogues at micro and macro levels of understanding education. For instance, we should analyse systems thinking, critical thinking, self-regulation and active listening. Data analysis should move across individual tutoring systems and evaluate students' skills for the 21st Century (Woolf et al. 2013).

Fourth challenge: Developing quality and inclusive data systems

Given that data fuel AI, complete, reliable and timely data constitute an important prerequisite for installing AI-enhanced data analytics systems. A fully functional data analytics system with comprehensive and up-to-date data opens possibilities for AI-enabled predictive and machine learning algorithms. Data enable intelligent systems. Without the needed data, no sort of algorithm, no matter how sophisticated, can function properly. As such, a data-rich environment is a prerequisite to AI-enabled systems. However, data availability is a necessary yet insufficient condition. It follows that any AI-enabled system is only as good as the data it contains. After all, inaccurate data are likely to make machine learning algorithms generate incorrect outputs. Indeed, predictive algorithms can only make complete and accurate predictions if the data they are handling are itself complete and accurate.

However, many countries still struggle with collecting basic yet critical educational data. The UNESCO Institute for Statistics (UIS) cites the many hindrances to the efficient and effective collection and use of educational data (UIS, 2018b). Educational data should be open and usable at the school level. An EMIS should be able to generate analyses that are granular enough to help teachers and education administrators understand the key challenges while also being able to aggregate data to reveal trends that can inform policy development.

Furthermore, data must also account for inequities, providing insights, for example, on learning outcomes disaggregated according to demographic factors such as age, gender and socio-economic background (UNESCO, 2018). The ability to generate such analyses allows education systems to determine the educational disadvantage experienced by specific marginalised or vulnerable populations. However, data on disadvantaged groups still currently tend to be incomplete and even absent. For instance, a 2016 study by UNICEF showed that, out of 40 countries surveyed, 19 had no data at all on children with disabilities; for many countries that did have data, it was only specified that the child was on a special-needs programme but failed to indicate the disability (UNICEF, 2016). Data on refugees and internally displaced populations (IDPs) also remain limited, with most of those data coming from camps and camp-like settings (UNESCO & UNHCR, 2016). Refugees studying in national schools are also frequently not identified as refugees in national education statistics, thus making it more difficult to monitor and evaluate their learning outcomes. Furthermore, since the collection and analysis of education data usually happens on a once-a-year basis, the data are often unable to convey accurate information on transient populations.

It is also important to note that the education system itself is not the only source of data relevant to learning provision. Household data, as specifically mentioned by the UIS, can also provide insights on exogenous factors that might account for learning difficulties at school. The same can be said of data coming from other ministries, e.g. the ministry of health. Data on nutrition can be used to report on, for instance, the design of school meal programmes. This speaks to the importance of data integration: When government systems are integrated, more data become shared and available across all sectors. This data sharing means that more data can be used by the education sector to run AI algorithms and consequently, more possibilities to generate analyses, models or predictions.

The understanding that data are capable of yielding direct value and are useful across all levels of the education system is critical to ensuring data quality. In fact, the extent of data use at least partly determines data quality (Orr, 1998). After all, the more useful data is to a stakeholder, the more incentive there is for that stakeholder to ensure that the data is produced in an accurate and timely manner. Open data can also be an impetus for data use. The ability to access data and metadata does not only allow intermediaries (e.g. NGOs) and community stakeholders to draw direct value and mine insights from education data, but this transparency also creates a greater sense of accountability on the part of ministries of education for the improvement of educational outcomes (UNESCO, 2018). Open data are anchored on the discourse of data 'prosumption', i.e., stakeholders do not only consume data but are also involved in data production and interpretation (Williamson, 2015). Stakeholders must have access to data analytics if they are to be involved in the improvement of the education system.

AI-powered technologies provide opportunities to make educational data more useful at each level of the education system. Learning analytics, for instance, as demonstrated in the examples provided in this paper, provide educators with real-time insights about students' individual progress

and learning patterns, thus allowing the former to make real-time adjustments to their instructional approach. Furthermore, the real-time generation of data could also mean that student-level data are constantly updated, i.e., if the learning analytics systems used at the school level directly feed into a system-level EMIS. This real-time data capture also provides opportunities to expand data sets on refugees and IDPs, given how traditional annual data collection schedules have produced insufficient data on such populations. Automated analytics also make it easier to disaggregate data according to various demographic factors, thus also making it relatively easier to identify sources of educational inequality. Of course, having an adequate amount of data is a prerequisite to producing such analyses. As such, countries with weak or incomplete data systems should focus on strengthening their data systems and bridging their data gaps.

It must be acknowledged, however, that while technologies for capturing data are indeed becoming more and more powerful, their costs could be prohibitively high, particularly for low- and middle-income countries. As such, the costs of such data systems need to be carefully examined and weighed against the potential benefits. While numerous governments are able to produce large amounts of education data to inform decision-making, many countries are still unable to do so (Custer et al., 2018). Many efforts to remedy this problem have fallen short since they focused on the procurement of more sophisticated data reporting technologies, even when the issue lay in weak institutional processes that would result in faulty, incomplete and unused data. This harks back to strong institutional and organisational processes being a prerequisite to the installation of any data-dependent system, including AI technology. As such, institutional capacity-building becomes a crucial investment, particularly for countries whose data processes remain ad hoc and thus unable to produce consistent, relevant and timely data.

Fifth challenge: making research on AI in education significant

While we can reasonably expect increased research on AI in education in the coming years, it is also worth recalling the difficulties that the education sector has in taking stock of educational research in a significant way for practice and policy-making. The particular domain of research on educational technology clearly demonstrates that what researchers state as key research questions are quite often unrelated to teachers' needs.

Technology's potential to transform education has often been stated, though it is widely accepted that, for various reasons, this potential has yet to be harnessed as expected in developed countries (Conlon & Simpson, 2003; Cuban, 2001; OECD, 2015; Sandholtz, 2001) or developing countries (Power, Gater, Grant, & Winters, 2014). When reviewing how decisions about technology use in education are made, it is striking how little is known about the effects of using technology on the quality of school education, and, more specifically, which particular uses of technology can result in better learning. Current developments regarding AI in education seem to be yet another instance of this well-known phenomenon. This is a far from optimal state of affairs in poorer, resource-constrained developing contexts, where technology-based reforms are being pushed as the remedy for poor economic and social conditions. As the emphasis of many national initiatives in this context is usually put on granting access to technology as an intrinsic added-value, not much research has been conducted on the actual effects on learning.

There is a great need to sustain AI applications in education in ways that contribute to making schools better suited to the needs and activities of an AI-empowered society. To do so effectively is not just a matter of financing, but also of monitoring and assessing what works in education, disseminating it in ways that are meaningful for teachers and suitable for scaling up. The pending issue of how AI use relates to educational performance can be explored through correlations and will be done even more in the future, but accompanying empirical research and experiments will have to be carried out so as to build a useful knowledge base. Rather than claiming that more research must be done, the conclusion is that research must be oriented differently.

It is well known that the adoption of an innovation essentially depends on end users perceptions of the advantages of applying a new strategy in relation to what they are currently using (Rogers, 2003). Applying this principle to the concrete example of technology in education, it might be expected that AI can support the design of new strategies to achieve the following:

- learn better, e.g. in a more personalised manner
- learn more, i.e. achieve better outcomes from learning
- learn different things, i.e. achieve learning goals that only technology can enable

Research should ascertain the strategies that will make this possible, the conditions in which they would be feasible and, ultimately, capable of being applied widely. The feasibility issue is extremely important for school learning because there may be many strategies that could prove to be incompatible with the current configuration of schools and even the teaching profession.

Education research, relating to technology and also in general, is complicated by the very nature of its subject matter and because contextual conditions limit its capacity to provide results from which generalisations can be drawn, thereby affecting its ability to contribute to the creation of universally valid theories.

In education, there is an omnipresent problem of these so-called "ubiquitous interactions", i.e. the sheer number of variables that increase the difficulty of isolating impacts or combining the results of different studies (Lederman, 2003). As it is very difficult to isolate the influence of instructional strategies, any example relating to strategies to improve learning would serve student skills and abilities, socioeconomic status, motivation and the interaction between all these variables.

Finally, there is also a need for a localised and decentralised examination of what is taking place in classrooms, particularly in the context of developing countries. Despite that the international agenda for education seems to suggest that AI may bring only benefits, there is an understanding of "local needs in local contexts" in order to find more broad strategies that could be supported by AI, replicated and also capable of being scaled up. There is no such thing as a universal technology-based solution for the current educational challenges of small developing states, which will not be the case with AI either. Well-oriented, local research can help recognise teachers as actors and not mere beneficiaries or users of well-packed technology solutions. No doubt, research has a role to play in investigating further into the role that technology solutions play in improving the quality of education, including developing countries. However, the right research questions must be asked. Given that educational phenomena are quite complex and multi-faceted, the right questions are not about whether or not to use AI in education at all, but about which AI solutions can best suit the evolving learning requirements that each individual teacher has to manage in the classroom considering the reality of teaching conditions and opportunities. AI may shine and speak by itself, but unless it is properly embedded into sound teacher practices no educational effects will ever be seen.

Sixth challenge: ethics and transparency in data collection, use and dissemination

The ethical quandaries that come with the large-scale collection, production, analysis and dissemination of data about persons are another important consideration in the development of any concerted policy framework for AI. It must be noted, though, that seeking to understand the ethical implications of new technologies is by no means a new pursuit. Over the past 30 years, scholars and practitioners have sought to define some form of computer or information ethics that can be summarised as a question "What does the ethical use of technology look like?" (Floridi & Taddeo, 2016). However, the emergence of data science as the "latest phase of the information revolution" has shifted the discourse from *information* ethics to *data* ethics. Experts have forwarded the notion that "it is not the hardware that causes ethical problems… [I]t is what the hardware does with the software and the data that represents the source of our new difficulties" (Floridi & Taddeo, 2016).

While AI has many positive applications, there are also societal and ethical concerns that should be addressed. Most people have at least read something about AI systems discriminating unfairly (ProPublica, 2016; Mic, 2016; Reuters, 2018), taking life-impacting decisions in a non-transparent way (Cathy O'Neil, 2016), ready to take all our jobs (McKinsey Global Institute, 2017) and set to wrest control from humans (The Register, 2018). While there is no need to panic, all those concerns should nevertheless be considered when AI becomes massively applied in our societies and especially because the technology is improving quickly insofar as what is impossible today could be possible tomorrow. There is much work going on today that tries to come up with answers to such concerns (The European Commission, 2018; Dillon, 2018; Future of Humanity, 2018; Nuffield 2018).

How are those AI concerns impacting education and especially digital education?

The following is an explanation on how these concerns may arise from an educational perspective.

- Access to educational systems. Increasingly more educational institutions are using Machine Learning algorithms to accept or reject students. Two potential problems with this approach include:
  - Lack of explainability. Some ML techniques (e.g. Deep Learning) cannot easily explain why certain students are accepted while others are rejected. Should a rejected student have the right to understand those reasons?
  - Unfair discrimination. When Machine Learning algorithms are trained on a certain data set (let's say with students from a Western European country), then the result might not be directly applicable to students from other parts of the world. The training data set might be biased towards a certain group and therefore might discriminate unfairly when used on a different group.
- Recommendations to individual students. Like the previous point, if recommendations are "machine-learned" based on a large set of previous data, the resulting recommendation might not be adequate for students from a different target group. Of course, if the recommendations are based on the individual learning history of the student, then this problem does not exist.
- Personal data concentration. In the case that -like in the digital world- educational platforms will be owned by a few major players in the world, two concerns arise
  - The concentration of personal (student and teacher) information, which might create a privacy risk. Large concentrations of personal data are an attractive target for cyber criminals.
  - Dominating platforms could forge data monopolies cornering the market on the ability to develop the best algorithms. This would give them a great degree of power and also increase the "explainability" concern when those "best" algorithms take the majority of educational decisions for student learning paths.
- Liability. What happens if the automated decisions that guide students in their learning process turn out to be wrong? Who or what is responsible and accountable? The platform owner? The assigned teacher? The algorithm?
- Impact on work. If AI systems automate increasingly more tasks that are normally performed by teachers, what happens to their jobs? AI systems can assess the student's initial level, guide the student through the course based on collective intelligence combined with individual experience, automatically evaluate test results and even automate the student-teacher interaction using chatbots and NLP techniques.

While those concerns need to be dealt with, we should not forget that without using AI for education, the outcome might be much worse. For one thing, AI can automate many mechanical, repetitive and boring tasks and this gives human teachers more time for more complex cases, leveraging the human interaction and make sure that more students become successful. Another positive aspect is that AI in Education can help scale up upskilling the workforce to become AI-ready. The workers whose jobs will be mostly affected by AI automation have an opportunity to get trained in skills needed to work alongside AI systems.

Data privacy and security almost immediately come up in discussions regarding data ethics. The main challenge lies in being able to use personal data while ensuring that personally identifiable information and individual privacy preferences are protected. Installing necessary safeguards to prevent data theft is also critical. In education, this becomes even more challenging in the context of young learners, who, in legal terms, cannot yet provide express consent regarding the collection and use of their personal data.

Despite these important concerns, however, less than 30% of countries across all regions, excluding Europe, have comprehensive data protection laws in place (UNCTAD, 2016). This is at least partly due to a lack of understanding of legal issues in data privacy among policymakers and law enforcement entities (UNCTAD, 2016). While the increase in global, regional and national frameworks concerning the protection of personal data certainly marks a growing understanding of how urgent the issue is, many of these frameworks still do not offer adequate protection to

citizens, both in policy and practice – particularly in developing countries (World Wide Web Foundation, 2017).

A 2016 study by the United Nations Conference on Trade and Development (UNCTAD) reveals growing public distrust in systems that use and collect personal data. People are often uncertain about how their data will be used after giving their consent (UNCTAD, 2016). Governments should be particularly concerned about this growing distrust, especially given the generally increasing amount of data being collected by the public sector with the rise, for instance, of digital identification systems (World Wide Web Foundation, 2017). While it may be true that these digitisation efforts contribute to improved service delivery, concerns about potential data breaches and expanded government surveillance are nonetheless abound – and reasonably so. Given these concerns, legal frameworks therefore need to not only ensure that personal data are strongly protected against cyber-attacks; they must also reassure citizens that their data will not be used for unwarranted surveillance (World Wide Web Foundation, 2017).

Governments must clearly communicate the scope and purpose of any data collection exercise: what sort of data will be collected, for what end the data will be used, and what consequences, intended or unintended, might occur within the data model. This not only increases citizen willingness to participate in the exercise, but it also allows citizens to weigh its benefits against its potential risks, thus allowing them to make more informed decisions about consenting to the use of their data. This is yet again grounded on the notion of data 'prosumption'. As sources of data, citizens must know why their data are being collected and be able to provide their consent in an informed manner. Furthermore, data collection should be anchored on the minimisation principle, i.e. to use the minimum amount of data required to achieve public benefit (World Wide Web Foundation, 2017).

The ethical issues discussed above convey a clear need for policy frameworks for the use of AI in education to incorporate an ethical orientation. The collection and use of individual data, even when used for improving learning, should always be anchored on express and informed consent, transparency, equity and fairness.

Conclusions

To date, non-State actors, particularly the private sector, have principally led the response to AI in most countries. Tech giants, concentrated largely in the United States and China, for instance, are dominating the development of AI-enabled technologies. The rise of tech startups has also played a significant role in accelerating AI penetration. The rapid expansion of the EdTech industry is particularly notable, with AI-enabled learning technologies seeing increasing use in the classroom.

Nonetheless, given the increasing ubiquity of AI in all aspects of human activity, more and more governments are beginning to actively implement concrete responses to AI. Some countries such as France, Australia, Estonia, South Korea, China and the United States have even released national AI strategies. In all such responses, education is an comprehensive element. However, in developing countries, these discussions are far off and limited by structural obstacles (basic technological infrastructure, high profile trained human resources in the field of AI, etc.). What are the possible paths to unfurling comprehensive strategies in developing countries to integrate AI in education? What is the international community's role in helping bridge the digital gap between countries that is increasing their social divide?

This paper discussed these questions using examples and reflections on two main axes through which the education sector can leverage and adapt to AI: (1) using AI to generate real-time insights towards improving educational outcomes; and (2) rethinking and redeveloping educational programmes to make them more responsive to changes brought about by AI.

Some countries are taking advantage of the abundance of educational data that came with the advent of the Information Age. These countries and their respective educational institutions have begun harvesting insights from large masses of data to provide more personalised learning experiences. Of course, the elephant in the room begs noticing, i.e. the ethical implications of collecting and mining data from learners. As such, any concerted policy framework regarding the use of AI in education needs to address this issue; education systems must clearly delimit

how learner data are used and be expressly based on learners' consent to their data being used.

Education systems have also been actively reforming themselves to ensure that learners are acquiring the skills required by an AI-enabled future workplace. These reforms are happening across all educational sub-sectors, from the early years to continuing education. This lifelong learning orientation is of course appropriate in light of how fast AI technologies evolve. As such, this process of rethinking and redeveloping educational programmes in response to AI might need to become a regular and continuous process.

Since these reforms are taking place in light of an AI skills gap, there also needs to be more dialogue and collaboration between industry and the education sector. Bridging this skills gap is not the sole responsibility of the education sector; if educational institutions are to produce a workforce that satisfies the needs of industry, it would be in the best interests of industry to be more involved in the development and delivery of learning programmes.

UNESCO, given its leadership role in the SDG 4-Education 2030 Agenda, has the mandate to coordinate with national governments and mobilise non-State actors, including NGOs and private enterprises. Furthermore, UNESCO's extensive network of businesses, policymakers and practitioners working within the education sector, allows the Organisation to broker partnerships between learning solution providers. Moreover, the Organisation's normative function allows it to define fundamental criteria and standards for the selection of appropriate AI technologies, in light of SDG 4 objectives. Moreover, UNESCO's mandate makes the Organisation competent to provide technical assistance to countries seeking to move towards AI-enabled education systems.

Inevitably, AI is a field that spurs innovation and, by doing so, increases countries' competitiveness. Countries will continue competing in such a rich and rapidly evolving arena. Yet, at least when it comes to education, there is also room for cooperation, whose basis is knowledge sharing. To promote the discussion and the relevance of adopting comprehensive perspectives of AI in education there is a need of more information about how countries are moving forward in this uncertain and constantly changing territory. The creation of an **Observatory of AI in education** to look at relevant initiatives of AI in education and to inform on national and international AI strategy plans may be seen as a platform for knowledge sharing and peer learning. This observatory (with strong emphasis on developing countries) will help increase the evidence-based dialogue among decision makers.

Indeed, there have been multiple responses to the changes accompanying the rise of AI in various areas of human activity as shown by the examples provided in this paper. However, these responses remain independent of a holistic and concerted policy framework for AI in education. Nonetheless, it is important to note that the initiatives presented are worthwhile starting measures that can guide the creation of a coherent policy framework. It is of course critical to engage different sectors in the development of such a framework, since the impact of AI sweeps across sectors.

ANNEX

AI definition and related concepts

A reference book on the AI domain: Russell, Stuart J. & Peter Norvig called **Artificial Intelligence: A Modern Approach** (2010). Refer to the figure below for definitions based on different dimensions.

The definitions in the top quadrants address thought processes and reasoning while the ones in the bottom quadrants address behaviour. The definitions on the left measure success in terms of fidelity to human performance while the ones on the right measure success against an ideal performance measure, referred to as rationality. A system is rational if it does the "right thing", given what it knows. A human-centred approach must be, at least partly, an empirical science, involving observations and hypotheses about human behaviour. A rationalist approach involves a combination of mathematics and engineering.

The full references in the image are:

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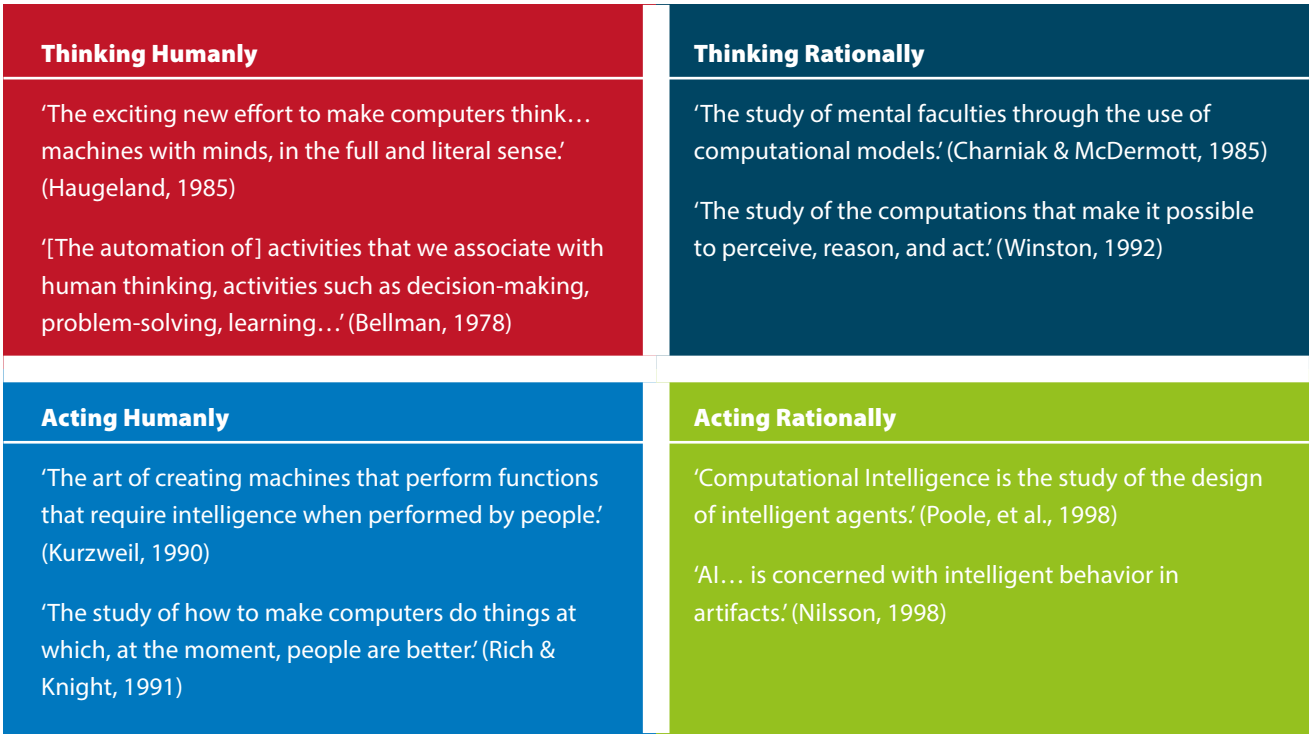
Different proposed definitions for:

Machine Learning

i) The field of Machine Learning seeks to answer the question "How can we build computer systems that automatically improve with experience, and what are the fundamental laws that govern all learning processes?

- Mitchell, Tom Michael. The discipline of machine learning. Vol. 9. Pittsburgh, PA: Carnegie Mellon University, School of Computer Science, Machine Learning Department, 2006.

ii) Machine learning algorithms can figure out how to perform important tasks by generalising from examples.



– Domingos, Pedro. A few useful things to know about machine learning. Communications of the ACM 55.10 (2012): 78-87.

iii) Machine Learning is the science (and art) of programming computers so they can learn from data.

– Géron, Aurélien. **Hands-on machine learning with Scikit-Learn and TensorFlow: concepts, tools, and techniques to build intelligent systems**. O'Reilly Media, Inc., 2017.

iv) Machine learning tools are concerned with endowing programs with the ability to "learn" and adapt.

– Shalev-Shwartz, Shai, and Shai Ben-David. **Understanding machine learning: From theory to algorithms**. Cambridge university press, 2014.

Deep Learning

i) Deep learning is a specific subfield of machine learning: a new take on learning representations from data that puts an emphasis on learning successive layers of increasingly meaningful representations. The "deep" in deep learning isn't a reference to any kind of deeper understanding achieved by the approach; rather, it stands for this idea of successive layers of representations. The depth of the model is the amount of layers contributing to a data model. Perhaps more suitable names for the field could have been layered representations learning and hierarchical representations learning. Modern deep learning often involves tens or even hundreds of successive layers of representations, which are all learned automatically from exposure to training data. Meanwhile, other approaches to machine learning tend to focus on learning only one or two layers of representations of the data and sometimes referred to as shallow learning.

In deep learning, these layered representations are (nearly always) learned via models called neural networks, structured in literal layers stacked on top of each other.

– Chollet, Francois. **Deep learning with python**. Manning Publications Co., 2017.

ii) The true challenge to artificial intelligence proved to be solving tasks that are easy for people to perform but hard for people to describe formally, e.g. problems that we solve intuitively and feel automatic like recognising spoken words or faces in images.

Deep learning allows computers to learn from experience and understand the world in terms of a hierarchy of concepts, with each concept defined in terms of its relation to simpler concepts. By gathering knowledge from experience, this approach avoids the need for human operators to formally specify all the knowledge that a computer needs. The hierarchy of concepts allows computers to learn complicated concepts by building them out of simpler ones. A graph showing how these concepts are built on top of each other would be deep (with many layers). For this reason, this approach to AI is referred to as sdeep learning.

– Goodfellow, Ian, et al. **Deep learning**. Vol. 1. Cambridge: MIT press, 2016.

Big Data

i) Big data is a combination of data-management technologies that have evolved over time. Big data lets organisations store, manage and process vast amounts of data at the right speed and at the right time to gain the right insights. The key to understanding big data is that data should be managed so that they can meet the business requirement that a given solution is designed to support.

– Hurwitz, Judith S., et al. **Big data for dummies**. John Wiley & Sons, 2013.

ii) Big data is a blanket term for any collection of data sets so large or complex that it becomes difficult to process them using traditional data management techniques such as, for example, the RDBMS (relational database management systems).

The characteristics of big data are often referred to as the three Vs:

- Volume — How much data are there?
- Variety — How diverse are different types of data?
- Velocity — At what speed are new data generated?

Often these characteristics are complemented with a fourth V, Veracity: How accurate are the data? These four properties make big data different from the data found in traditional data management tools.

– Cielen, Davy, Arno Meysman, and Mohamed Ali. **Introducing data science: big data, machine learning, and more, using Python tools**. Manning Publications Co., 2016.

Data Mining

i) Data mining is the process of discovering interesting patterns and knowledge from large amounts of data. The data sources can include databases, data warehouses, the Web, other information repositories or data dynamically streamed into the system.

   – Han, Jiawei, Jian Pei, and Micheline Kamber. **Data mining: concepts and techniques**. Elsevier, 2011.

ii) Data mining is the process of discovering insightful, interesting and novel patterns, and descriptive, understandable and predictive models from large-scale data

   – Zaki, Mohammed J., Wagner Meira Jr, and Wagner Meira. **Data mining and analysis: fundamental concepts and algorithms**. Cambridge University Press, 2014.

iii) Data mining is the analysis of (often large) observational data sets to find unsuspected relationships and summarise the data in novel ways that are both understandable and useful to the data owner

   – Hand, David J., Heikki Mannila, and Padhraic Smyth. **Principles of Data Mining**. MIT press, 2001.

Data Analytics

i) Big Data Analytics is a way of extracting value from these huge volumes of information, and it drives new market opportunities and maximises customer retention.

   – Zakir, Jasmine, Tom Seymour, and Kristi Berg. **Big Data Analytics**. Issues in Information Systems 16.2 (2015).

ii) Data analytics is the science of drawing insights from raw information sources. https://www.investopedia.com/terms/d/data-analytics.asp

iii) Data analytics is the pursuit of extracting meaning from raw data using specialised computer systems. These systems transform, organise and model the data to draw conclusions and identify patterns. https://www.informatica.com/ca/services-and-training/glossary-of-terms/data-analytics-definition.html#fbid=ETHvIPIs4QM

iv) Data Analytics (DA) is the method of examining and analysing raw data so that conclusions can be drawn. Data analytics is a valuable part of science-centred industries in verifying or disproving current theories or models. The purpose of DA is to sort through data to arrive at a conclusion. https://study.com/academy/lesson/what-is-data-analytics-definition-tools.html

Learning Analytics

In this context, learning Analytics (LA) is an emerging discipline that pursues improvement in teaching and learning by a critical evaluation of raw data and the generation of patterns that characterise learner habits, predict learner responses and provide timely feedback. Moreover, LA supports decision-making, tailors readable content, simplifies realistic assessments and provides personal supervision of learners' progress. The goal is to scale the real-time exploitation of LA by learners, teachers/academics and educational computer-based systems to enhance learners' accomplishments at course and individual levels.

   – Peña-Ayala, Alejandro, **Learning Analytics: Fundaments, Applications, and Trends: A View of the Current State of the Art to Enhance e-Learning**. Vol. 94. Springer, 2017.

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Artificial Intelligence in Education: Challenges and Opportunities for Sustainable Development

Artificial Intelligence is a booming technological domain capable of altering every aspect of our social interactions. In education, AI has begun producing new teaching and learning solutions that are now undergoing testing in different contexts. This working paper, written for education policymakers, anticipates the extent to which AI affects the education sector to allow for informed and appropriate policy responses. This paper gathers examples of the introduction of AI in education worldwide, particularly in developing countries, discussions in the context of the 2019 Mobile Learning Week and beyond, as part of the multiple ways to accomplish Sustainable Development Goal 4, which strives for equitable, quality education for all.

First, this paper analyses how AI can be used to improve learning outcomes, presenting examples of how AI technology can help education systems use data to improve educational equity and quality in the developing world. Next, the paper explores the different means by which governments and educational institutions are rethinking and reworking educational programmes to prepare learners for the increasing presence of AI in all aspects of human activity. The paper then addresses the challenges and policy implications that should be part of the global and local conversations regarding the possibilities and risks of introducing AI in education and preparing students for an AI-powered context.

Finally, this paper reflects on future directions for AI in education, ending with an open invitation to create new discussions around the uses, possibilities and risks of AI in education for sustainable development.

4 QUALITY EDUCATION

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Outcome document of the International Conference on Artificial Intelligence and Education

'Planning education in the AI era: Lead the leap'

16 – 18 May 2019 Beijing, People's Republic of China

UNESCO Education Sector

Education is UNESCO's top priority because it is a basic human right and the foundation on which to build peace and drive sustainable development. UNESCO is the United Nations' specialized agency for education and the Education Sector provides global and regional leadership in education, strengthens national education systems and responds to contemporary global challenges through education with a special focus on gender equality and Africa.

The Global Education 2030 Agenda

UNESCO, as the United Nations' specialized agency for education, is entrusted to lead and coordinate the Education 2030 Agenda, which is part of a global movement to eradicate poverty through 17 Sustainable Development Goals by 2030. Education, essential to achieve all of these goals, has its own dedicated Goal 4, which aims to ***"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."*** The Education 2030 Framework for Action provides guidance for the implementation of this ambitious goal and commitments.

United Nations Educational, Scientific and Cultural Organization

Education Sector

Education 2030

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Preamble

1. We, the participants of the *International Conference on Artificial Intelligence (AI) and Education*, including 50 government ministers and vice ministers, as well as around 500 international representatives from more than 100 Member States, United Nations agencies, academic institutions, civil society and the private sector, met in Beijing, People's Republic of China, from 16 to 18 May 2019. We express our sincere gratitude to UNESCO and the Government of the People's Republic of China for co-organizing the conference and for the warm welcome and generous hospitality of the Beijing Municipal Government.

2. We reaffirmed the commitment made in the 2030 Agenda for Sustainable Development, particularly Sustainable Development Goal (SDG) 4 and its targets, and discussed the challenges faced by education and training systems in achieving SDG 4. We are committed to leading appropriate policy responses aimed at the systematic integration of AI and education to innovate education, teaching and learning, and at leveraging AI to accelerate the delivery of open and flexible education systems that enable equitable, relevant and quality lifelong learning opportunities for all that will contribute to achieving the SDGs and the shared future for mankind.

3. Recalling the *Qingdao Declaration* adopted in 2015 on leveraging information and communication technology (ICT) to achieve SDG 4, which stated that emerging technologies must be harnessed to strengthen education systems, access to education for all, quality and effective learning, and equitable and more efficient service provision, we are cognizant of the urgency of reaffirming and renewing this commitment as we move towards an era characterized by the widespread application of AI.

4. We reviewed the recent trends in the evolution of AI and its profound impact on human societies, economies and the labour market, as well as on education and lifelong learning systems. We examined the implications of AI for the future of work and skills development and considered its potential for reshaping the core foundations of education, teaching and learning.

5. We recognize the complexity and rapid development of the AI field, with its multiple understandings, broad range and varied definitions, as well as the diversity of its applications in different contexts and the ethical challenges it raises.

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, and for sustainable development.

7. We also affirm that the development of AI should be human-controlled and centred on people; that the deployment of AI should be in the service of people to enhance human capacities; that AI should be designed in an ethical, non-discriminatory, equitable, transparent and auditable manner; and that the impact of AI on people and society should be monitored and evaluated throughout the value chains.

We RECOMMEND that governments and other stakeholders in UNESCO's Member States, in accordance with their legislation, public policies and practices, consider implementing the following actions in response to the education-related opportunities and challenges presented by AI:

Planning AI in education policies

8. Be mindful of the multidisciplinary nature of AI and its impacts; align AI in education with public policies, particularly education policy; adopt whole-government, intersectoral and multistakeholder approaches to the planning and governance of AI in education; and set strategic priorities based on local challenges in achieving SDG 4 and its targets as well as the other SDGs. Plan and develop coherent system-wide strategies for AI in education that are aligned and integrated with education policies, within a lifelong learning perspective.

9. Be mindful of the investment requirements for implementing AI in education policies and programmes. Consider the trade-offs between

different education policy priorities and identify different sources of funding, including national (public and private), international and innovative funding mechanisms. Consider also the potential of AI to combine and analyse multiple data sources to improve the efficiency of decision-making.

AI for education management and delivery

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.

AI to empower teaching and teachers

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.

AI for learning and learning assessment

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.

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.

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.

Development of values and skills for life and work in the AI era

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 anticipate and 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 develop local AI talent, in order to create a massive pool of local AI professionals who have the expertise to design, programme and develop AI systems.

AI for offering lifelong learning opportunities for all

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.

Promoting equitable and inclusive use of AI in education

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.

Gender-equitable AI and AI for gender equality

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 to 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 AI workforces and employers.

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 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.

Monitoring, evaluation and research

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 learning 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.

We RECOMMEND that international organizations and partners active in the field consider implementing the following actions:

Financing, partnership and international cooperation

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 towards building an international community with common views on AI and education.

36. Align international cooperation with national needs for the development and 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 information sharing and the sharing of promising practices, as well as coordination and complementary actions among countries.

37. Provide adequate platforms for 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 on leveraging AI for SDG 4.

38. Create multistakeholder partnerships and mobilize resources to reduce the AI divide and increase investment in the application of AI in education.

We INVITE the Director-General of UNESCO to seek to implement the following actions:

39. Establish an 'AI for Education' platform to act as a clearinghouse for open-source AI courses, AI tools, examples of AI in education policies, regulatory frameworks and best practices on AI in education, with a view towards promoting the use of AI for SDG 4, supporting debate on the future of education and learning, and making open-source AI resources and courses accessible to all.

40. Develop guidelines and resources in consultation with Member States to support the development of policies and strategies for effective and equitable use of AI in education. Support the capacity-building of education policy-makers.

41. Reinforce the leading role of UNESCO in AI in education across concerned sectors, divisions or departments, and mobilize the Organization's institutes and networks.

42. Support the integration of AI skills into ICT competency frameworks for teachers and support countries in training teaching staff on working in AI-rich education settings.

43. Further expand UNESCO's cooperation in the field of AI in education with relevant United Nations and multilateral partners, as well as with regional development banks and organizations and with the private sector.

44. Undertake appropriate regional and international follow-up actions to the Conference, acting in cooperation with development partners active in this field, to build on and extend the outreach of the Consensus.

Organisation
des Nations Unies
pour l'éducation,
la science et la culture

FRANÇAIS

CONSENSUS DE BEIJING
sur l'intelligence artificielle et l'éducation

Document final de la Conférence internationale sur l'intelligence artificielle et l'éducation

« Planifier l'éducation à l'ère de l'IA : un bond en avant »

16 – 18 mai 2019 Beijing, République populaire de Chine

Secteur de l'éducation de l'UNESCO
L'éducation est la priorité première de l'UNESCO car c'est un droit humain fondamental et la base pour construire la paix et faire progresser le développement durable. L'UNESCO est l'institution des Nations Unies spécialisée pour l'éducation et son Secteur de l'éducation assure un rôle moteur aux niveaux mondial et régional dans ce domaine, renforce les systèmes nationaux d'éducation et répond aux défis mondiaux actuels par le biais de l'éducation, en mettant tout particulièrement l'accent sur l'égalité des genres et l'Afrique.

L'agenda mondial Éducation 2030
En tant qu'institution des Nations Unies spécialisée pour l'éducation, l'UNESCO est chargée de diriger et de coordonner l'agenda Éducation 2030, qui fait partie d'un mouvement mondial visant à éradiquer la pauvreté, d'ici à 2030, à travers 17 Objectifs de développement durable. Essentielle pour atteindre chacun de ces objectifs, l'éducation est au coeur de l'Objectif 4 qui vise à « ***assurer l'accès de tous à une éducation de qualité, sur un pied d'égalité, et promouvoir les possibilités d'apprentissage tout au long de la vie*** ». Le Cadre d'action Éducation 2030 définit des orientations pour la mise en œuvre de cet objectif et de ces engagements ambitieux.

UNESCO
Organisation des Nations Unies pour l'éducation, la science et la culture

Secteur de l'éducation

Éducation 2030

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Préambule

1. Nous, participants à la *Conférence internationale sur l'intelligence artificielle et l'éducation*, au nombre desquels figuraient 50 ministres et vice-ministres, près de 500 représentants internationaux de plus de 100 États membres, d'organismes des Nations Unies, d'établissements universitaires, de la société civile et du secteur privé, nous sommes réunis à Beijing, en République populaire de Chine, du 16 au 18 mai 2019. Nous exprimons notre sincère reconnaissance à l'UNESCO et au Gouvernement de la République populaire de Chine qui a coorganisé la conférence, et au Gouvernement de la municipalité de Beijing dont nous avons apprécié l'accueil chaleureux et la généreuse hospitalité.

2. Nous avons réaffirmé l'engagement pris dans le Programme de développement durable à l'horizon 2030 (Programme 2030) et en particulier l'Objectif de développement durable 4 (ODD 4) et ses cibles, et discuté des obstacles auxquels se heurtent les systèmes d'éducation et de formation dans la réalisation de cet objectif. Nous sommes résolus à apporter à ces défis des réponses politiques appropriées visant à intégrer systématiquement l'intelligence artificielle (IA) dans l'éducation pour innover l'éducation, l'enseignement et l'apprentissage, et à utiliser l'IA comme un levier afin d'accélérer la mise en place de systèmes éducatifs ouverts et flexibles, offrant à tous des possibilités d'apprentissage tout au long de la vie équitables, pertinentes et de qualité et contribuant ainsi à la réalisation des ODD et au futur collectif de l'humanité.

3. Rappelant la *Déclaration de Qingdao*, adoptée en 2015, sur le recours aux technologies de l'information et de la communication (TIC) comme moyen d'atteindre l'ODD 4, dans laquelle il est dit que les technologies émergentes doivent être mises à profit pour renforcer les systèmes éducatifs et promouvoir l'accès à l'éducation, un apprentissage de qualité et une offre de services plus efficace et plus équitable, nous sommes conscients qu'il est urgent de réaffirmer et de renouveler cet engagement alors que s'ouvre une ère caractérisée par l'utilisation généralisée de l'IA.

4. Nous avons passé en revue les tendances récentes de l'évolution de l'IA et leurs profondes répercussions sur les sociétés humaines, les économies et le marché du travail, ainsi que sur les systèmes d'éducation et d'apprentissage tout au long de la vie. Nous avons examiné les conséquences de l'IA sur l'avenir du travail et du développement des compétences et réfléchi à la manière dont l'IA pouvait remodeler les fondements mêmes de l'éducation, de l'enseignement et de l'apprentissage.

5. Nous reconnaissons la complexité et le développement rapide du secteur de l'IA, et les interprétations multiples, les définitions très variées et les applications diverses auxquelles l'IA se prête dans différents contextes, ainsi que les problèmes d'éthique qu'elle soulève.

6. Nous reconnaissons aussi les caractéristiques propres de l'intelligence humaine. Ayant à l'esprit les principes énoncés dans la *Déclaration universelle des droits de l'homme*, nous réaffirmons l'approche humaniste de l'UNESCO à l'égard de l'utilisation de l'IA, qui vise à protéger les droits de l'homme et à préparer tous les individus aux valeurs et aux compétences indispensables à une collaboration efficace entre l'être humain et la machine, dans la vie, dans l'apprentissage et au travail, ainsi qu'au développement durable.

7. Nous affirmons également que le développement de l'IA devrait être contrôlé par l'être humain et centré sur lui ; que l'IA devrait être déployée au service de l'être humain et pour renforcer ses capacités ; qu'elle devrait être conçue de manière éthique, non discriminatoire, équitable, transparente et vérifiable ; et que les incidences de l'IA pour l'être humain et la société devraient être suivies et évaluées à chaque étape des chaînes de valeur.

Nous RECOMMANDONS aux gouvernements des États membres de l'UNESCO et aux autres parties prenantes sur leurs territoires, d'envisager de mettre en œuvre, conformément à leur législation, à leurs politiques publiques et à leurs pratiques, les mesures suivantes pour prendre en compte les possibilités et les défis que représente l'intelligence artificielle dans le domaine de l'éducation :

Planifier l'IA dans les politiques de l'éducation

8. Garder à l'esprit le caractère pluridisciplinaire de l'IA et de ses effets ; faire en sorte que les applications de l'IA dans l'éducation soient conformes aux politiques publiques, en particulier les politiques de l'éducation ; adopter des approches engageant le gouvernement tout entier, intersectorielles et multipartites de la planification et de la gouvernance des politiques relatives à l'IA dans l'éducation ; et définir les priorités stratégiques en fonction des difficultés rencontrées au niveau local dans la réalisation de l'ODD 4 et de ses cibles, ainsi que des autres ODD. Planifier et élaborer des stratégies cohérentes à l'échelle du système, qui soient alignées sur les politiques de l'éducation et intégrées à celles-ci, dans la perspective de l'apprentissage tout au long de la vie.

9. Être attentifs aux investissements que requiert la mise en œuvre de politiques et de programmes visant à utiliser l'IA dans l'éducation. Chercher à concilier au mieux les différentes priorités des politiques éducatives et identifier diverses sources de financement, y compris des mécanismes de financement nationaux (publics et privés) et internationaux innovants. Prendre également en considération les possibilités offertes par l'IA de combiner et analyser de multiples sources de données pour améliorer l'efficacité de la prise de décisions.

L'IA au service de la gestion et de la mise en œuvre de l'éducation

10. Avoir à l'esprit la manière radicalement nouvelle dont les données sont utilisées pour transformer les processus de planification des politiques fondés sur des données factuelles. Envisager d'intégrer ou de développer des technologies et des outils d'IA pertinents pour perfectionner les systèmes d'information sur la gestion de l'éducation (SIGE) et améliorer ainsi la collecte et le traitement des données, de telle sorte que l'éducation soit gérée et dispensée de manière plus équitable, inclusive, ouverte et personnalisée.

11. Envisager également d'introduire dans différents établissements et cadres d'apprentissage de nouveaux modèles d'enseignement et de formation rendus possibles par l'utilisation de l'IA, afin de répondre aux besoins de différentes catégories d'acteurs telles que les élèves, le personnel enseignant, les parents et les collectivités publiques.

L'IA au service de l'autonomisation des enseignants et de leur enseignement

12. Garder à l'esprit que, si l'IA offre des possibilités de soutenir les enseignants dans l'exercice de leurs responsabilités éducatives et pédagogiques, l'éducation doit continuer de reposer essentiellement sur l'interaction et la collaboration humaines entre les enseignants et les apprenants. Être conscients que les enseignants ne peuvent être remplacés par des machines, et veiller à protéger leurs droits et leurs conditions de travail.

13. Examiner et définir de manière dynamique, dans le contexte des politiques relatives aux enseignants, les rôles joués par ces derniers et les compétences qui sont exigées d'eux, renforcer les centres de formation des enseignants et élaborer des programmes de développement des capacités appropriés, qui préparent le personnel enseignant à travailler efficacement dans des contextes éducatifs riches en ressources d'IA.

L'IA au service de l'apprentissage et de l'évaluation des acquis

14. Être au fait des tendances en ce qui concerne les possibilités offertes par l'IA de faciliter l'apprentissage et l'évaluation des acquis, et revoir et ajuster les systèmes éducatifs pour favoriser une intégration approfondie de l'IA et une transformation des méthodologies de l'enseignement. Envisager d'appliquer les outils d'IA disponibles ou de mettre au point des solutions d'IA novatrices pour faciliter l'exécution de tâches d'apprentissage bien définies dans différentes matières là où les avantages liés à l'utilisation de l'IA l'emportent clairement sur les risques, et de soutenir l'élaboration d'outils d'IA pour l'acquisition d'aptitudes et de compétences interdisciplinaires.

15. Encourager dans les écoles des essais pilotes sur l'utilisation de l'IA afin de faciliter l'innovation dans l'enseignement et l'apprentissage, en tirant les leçons des succès et en reproduisant à plus grande échelle les pratiques qui ont fait leurs preuves.

16. Appliquer ou mettre au point des outils d'IA pour faciliter les processus d'apprentissage adaptatifs ; mettre à profit les possibilités d'utiliser les données pour mesurer les multiples dimensions des compétences des élèves ; et promouvoir les évaluations à grande échelle et à distance.

Développer les valeurs et compétences nécessaires dans la vie et au travail à l'ère de l'IA

17. Être attentifs à la transformation systémique et à long terme du marché du travail qui résulte de l'adoption de l'IA, y compris la dynamique concernant l'égalité des genres. Mettre au point ou actualiser des mécanismes et des outils permettant d'anticiper et d'identifier les besoins de compétences présents et futurs liés au développement de l'IA, afin d'assurer la pertinence des programmes scolaires dans des économies, des marchés du travail et des sociétés en mutation. Intégrer les compétences relatives à l'IA dans les programmes et les qualifications de l'enseignement et de la formation techniques et professionnels (EFTP) et de l'enseignement supérieur, en tenant compte des aspects éthiques et des disciplines interdépendantes des sciences humaines.

18. Avoir conscience de l'émergence d'un ensemble de compétences liées à la maîtrise de l'IA qui sont indispensables à une collaboration efficace entre l'être humain et la machine, sans perdre de vue la nécessité de compétences fondamentales telles que la maîtrise de la lecture, de l'écriture et du calcul. Prendre des mesures au niveau institutionnel pour améliorer l'initiation à l'IA à tous les niveaux de la société.

19. Établir des plans à moyen ou long terme et prendre d'urgence des mesures pour aider les établissements d'enseignement supérieur et de recherche à mettre en place des cours et des programmes de recherche ou améliorer ceux qui existent déjà afin de cultiver les talents locaux en matière d'IA et créer ainsi un vivier important de professionnels locaux de l'IA possédant les compétences requises pour concevoir, programmer et développer des systèmes d'IA.

L'IA comme moyen d'offrir à tous des possibilités d'apprentissage tout au long de la vie

20. Réaffirmer que l'apprentissage tout au long de la vie est le principe qui doit guider la réalisation de l'ODD 4 et qu'il englobe l'éducation formelle et informelle. Adopter des plates-formes d'IA et une analytique de l'apprentissage fondée sur les données comme outils techniques essentiels pour construire des systèmes intégrés d'apprentissage tout au long de la vie, et offrant, à tout instant, en tous lieux et potentiellement à quiconque, la possibilité d'un apprentissage personnalisé adapté aux moyens de chacun. Exploiter le potentiel de l'IA s'agissant de mettre en place des parcours d'apprentissage flexibles, et de faciliter la capitalisation, la reconnaissance, la certification et le transfert des résultats d'apprentissage.

21. Garder à l'esprit qu'il importe d'apporter aux besoins des personnes les plus âgées, en particulier parmi les femmes, des réponses politiques appropriées, et d'encourager ces personnes à acquérir les valeurs et les compétences nécessaires pour utiliser l'IA dans leur vie de façon à briser les barrières à l'accès au numérique. Planifier et mettre en œuvre des programmes solidement financés pour donner aux travailleurs plus âgés des compétences et des options qui leur permettront de conserver une activité économique aussi longtemps qu'ils le souhaitent et de participer à la vie sociale.

Promouvoir une utilisation équitable et inclusive de l'IA dans l'éducation

22. Réaffirmer que la recherche de l'inclusion et de l'équité dans et par l'éducation et la volonté d'offrir à tous des possibilités d'apprentissage tout au long de la vie sont des conditions fondamentales de la réalisation de l'ODD 4 – Éducation 2030. Réaffirmer que toute percée technologique concernant l'utilisation de l'IA dans l'éducation est une occasion d'améliorer l'accès à l'éducation des groupes les plus vulnérables.

23. Faire en sorte que l'IA garantisse à tous des possibilités d'éducation et d'apprentissage de grande qualité, quels que soient le genre, le handicap, le statut social ou économique, l'origine ethnique ou culturelle ou la situation géographique de chacun. Le développement et l'utilisation de l'IA dans l'éducation ne doivent pas aggraver la fracture numérique, ni être entachés de préjugés à l'encontre des minorités ou des groupes vulnérables.

24. Veiller à ce que les outils d'enseignement et d'apprentissage fondés sur l'IA assurent efficacement l'inclusion des élèves présentant des troubles d'apprentissage ou un handicap, ainsi que de ceux qui font leurs études dans une autre langue que leur langue maternelle.

Une IA respectueuse de l'équité entre les genres et propice à l'égalité des genres

25. Souligner que l'écart entre les genres dans la maîtrise des compétences numériques contribue à la faible proportion de femmes parmi les professionnels de l'IA et aggrave les inégalités existantes entre les genres.

26. Affirmer notre engagement en faveur du développement d'applications de l'IA dans l'éducation qui soient exemptes de préjugés sexistes, et veiller à ce que les données utilisées pour développer l'IA soient attentives au genre. Les applications de l'IA devraient favoriser la promotion de l'égalité des genres.

27. Promouvoir l'égalité des genres dans l'élaboration d'outils d'IA, autonomiser les filles et les femmes en renforçant leurs compétences en matière d'IA afin d'assurer l'égalité entre les genres au sein du personnel et des employeurs du secteur de l'IA.

Veiller à une utilisation éthique, transparente et vérifiable des données et des algorithmes de l'éducation

28. Avoir à l'esprit que les applications de l'IA peuvent imposer différents types de biais inhérents aux données utilisées comme intrants pour mettre au point la technologie, ainsi qu'à la construction et à l'utilisation des processus et algorithmes. Être conscients des dilemmes que représente la recherche du juste équilibre entre le libre accès aux données et la protection de la vie privée. Être attentifs aux problèmes juridiques et aux risques éthiques liés à la propriété des données, à leur confidentialité et à leur disponibilité pour le bien public. Être conscients de l'importance de l'adhésion à des principes d'éthique, de confidentialité et de sécurité lors de la conception des outils d'IA.

29. Tester et adopter les technologies et outils nouveaux en matière d'IA qui garantissent la protection de la confidentialité et de la sécurité des données concernant les enseignants et les élèves. Soutenir des recherches solides et à long terme sur les questions éthiques plus fondamentales que soulève l'IA, en veillant à ce que l'IA soit utilisée à bonne fin et en prévenant ses applications néfastes. Élaborer des lois et des cadres réglementaires détaillés en matière de protection des données afin de garantir une utilisation et une réutilisation éthiques, non discriminatoires, transparentes et vérifiables des données relatives aux apprenants.

30. Ajuster les cadres réglementaires existants ou en adopter de nouveaux pour s'assurer que les outils d'enseignement et d'apprentissage fondés sur l'IA sont développés et utilisés de manière responsable. Faciliter la recherche sur les questions liées à l'éthique de l'IA, à la confidentialité et à la sécurité des données et aux préoccupations que suscitent les incidences négatives de l'IA sur les droits humains et sur l'égalité des genres.

Suivi, évaluation et recherche

31. Garder à l'esprit l'absence d'études systématiques sur les effets des applications de l'IA dans l'éducation. Soutenir la recherche, l'innovation et les analyses relatives à l'impact de l'IA sur les pratiques et les résultats de l'apprentissage, ainsi que sur l'émergence et la validation de nouvelles formes d'apprentissage. Adopter une approche interdisciplinaire de la recherche sur l'utilisation de l'IA dans l'éducation. Encourager les recherches comparatives transnationales et la collaboration entre pays.

32. Envisager la mise en place de mécanismes de suivi et d'évaluation permettant de mesurer l'impact de l'IA sur l'éducation, l'enseignement et l'apprentissage afin de produire des données factuelles qui constitueront une base valide et solide pour l'élaboration de politiques.

Nous RECOMMANDONS aux organisations internationales et à leurs partenaires œuvrant dans le domaine de l'intelligence artificielle d'envisager les mesures suivantes :

Financement, partenariats et coopération internationale

33. Surveiller et évaluer les incidences de la fracture créée par l'IA et les disparités entre pays en matière de développement de l'IA sur la base des données soumises volontairement par ces pays, et garder à l'esprit les risques de clivage entre ceux qui ont accès à l'IA et ceux qui n'y ont pas accès. Réaffirmer qu'il importe de répondre à ces préoccupations, en accordant une priorité particulière à l'Afrique, aux pays les moins avancés (PMA), aux petits États insulaires en développement (PEID) et aux pays touchés par un conflit ou une catastrophe naturelle.

34. Coordonner des actions collectives afin de promouvoir l'utilisation équitable de l'IA dans l'éducation dans le cadre de l'architecture internationale et régionale de l'agenda Éducation 2030, notamment par le partage de technologies, programmes et ressources en matière d'IA axés sur le renforcement des capacités, dans le plein respect des droits humains et de l'égalité des genres.

35. Soutenir les études prospectives sur les enjeux de demain liés à l'émergence de l'IA, et faciliter la recherche de stratégies et de pratiques efficaces visant à utiliser l'IA comme une source d'innovation dans l'éducation, de telle sorte que la communauté internationale ait une vision partagée des relations entre l'IA et l'éducation.

36. Axer la coopération internationale sur les besoins nationaux de développement et d'utilisation d'applications de l'IA dans l'éducation et de coopération intersectorielle afin de renforcer la prise en main du développement des technologies de l'IA par les professionnels de ce secteur. Renforcer l'échange d'informations et le partage de pratiques prometteuses, ainsi que la coordination et la complémentarité des actions entreprises par les différents pays.

37. Créer des plates-formes facilitant les échanges internationaux sur les cadres réglementaires, instruments et approches relatifs à l'IA dans l'éducation, notamment dans le cadre de la Semaine de l'apprentissage mobile de l'UNESCO et par l'intermédiaire d'autres organismes des Nations Unies, et promouvoir et mettre à profit de la sorte la coopération Sud-Sud et Nord-Sud-Sud afin de faire de l'IA un levier de la réalisation de l'ODD 4.

38. Créer des partenariats multipartites et mobiliser les ressources nécessaires pour réduire la fracture créée par l'IA et accroître les investissements en faveur de l'application de l'IA dans l'éducation.

Nous INVITONS la Directrice générale de l'UNESCO à s'efforcer de mettre en œuvre les mesures suivantes :

39. Créer une plate-forme « L'IA au service de l'éducation » qui servira de centre d'échange et de diffusion de cours Open Source, d'outils et d'exemples de politiques, de cadres réglementaires et de pratiques optimales en la matière, afin de promouvoir le recours à l'IA aux fins de la réalisation de l'ODD 4, de nourrir le débat sur l'avenir de l'éducation et de l'apprentissage et de rendre les ressources et cours Open Source relatifs à l'IA accessibles à tous.

40. Élaborer des principes directeurs et mobiliser des ressources en consultation avec les États membres pour faciliter la formulation de politiques et de stratégies en vue d'une utilisation efficace et équitable de l'IA dans l'éducation. Soutenir le renforcement des capacités des responsables des politiques de l'éducation.

41. Renforcer le rôle de chef de file de l'UNESCO en ce qui concerne l'IA dans l'éducation dans l'ensemble de ses secteurs, divisions ou départements concernés, et mobiliser les réseaux et instituts de l'Organisation.

42. Soutenir l'intégration des compétences en IA dans les référentiels de compétences TIC pour les enseignants et aider les pays à préparer le personnel enseignant à travailler dans des contextes éducatifs faisant fortement appel à l'IA.

43. Poursuivre l'élargissement des relations de coopération que l'UNESCO entretient, dans le domaine des applications de l'IA dans l'éducation, avec les organismes des Nations Unies et autres partenaires multilatéraux compétents, ainsi qu'avec les banques et organisations régionales de développement et avec le secteur privé.

44. Mener des actions appropriées de suivi de la Conférence aux niveaux régional et international, en coopération avec les partenaires du développement œuvrant dans ce domaine, afin de renforcer plus avant le Consensus et d'en étendre la portée.

Organización
de las Naciones Unidas
para la Educación,
la Ciencia y la Cultura

ESPAÑOL

CONSENSO DE BEIJING
sobre la inteligencia artificial y la educación

Documento final de la Conferencia Internacional sobre la Inteligencia Artificial y la Educación

"Planificación de la educación en la era de la inteligencia artificial: dirigir los avances"

16 – 18 de mayo de 2019 Beijing, República Popular China

El Sector de Educación de la UNESCO
La educación es la prioridad principal de la UNESCO porque es un derecho humano esencial y es la base para consolidar la paz e impulsar el desarrollo sostenible. La UNESCO es la organización de las Naciones Unidas especializada en educación y su Sector de Educación proporciona un liderazgo mundial y regional en la materia, fortalece los sistemas educativos nacionales y responde a los desafíos mundiales de nuestra época mediante la educación, con un enfoque especial en la igualdad de género y África.

La Agenda Mundial de Educación 2030
En calidad de organización de las Naciones Unidas especializada en educación, la UNESCO ha recibido el encargo de dirigir y coordinar la Agenda de Educación 2030. Este programa forma parte de un movimiento mundial encaminado a erradicar la pobreza mediante la consecución, de aquí a 2030, de 17 Objetivos de Desarrollo Sostenible. La educación, fundamental para alcanzar todos estos objetivos, cuenta con su propio objetivo específico, el ODS 4, que se ha propuesto ***"garantizar una educación inclusiva, equitativa y de calidad y promover oportunidades de aprendizaje durante toda la vida para todos".*** El Marco de Acción de Educación 2030 ofrece orientación para la aplicación de este ambicioso objetivo y sus compromisos.

UNESCO
Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura

Sector de Educación

Educación 2030

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Preámbulo

1. Nosotros, los participantes en la *Conferencia Internacional sobre la Inteligencia Artificial y la Educación,* incluidos 50 ministros y viceministros, así como 500 representantes internacionales de más de 100 Estados Miembros, de organismos de las Naciones Unidas, instituciones académicas, la sociedad civil y el sector privado, nos hemos reunido en Beijing (República Popular China) del 16 al 18 de mayo de 2019. Expresamos nuestro sincero agradecimiento a la UNESCO y al Gobierno de la República Popular China por haber coorganizado la Conferencia y por la cálida bienvenida y generosa hospitalidad del gobierno municipal de Beijing.

2. Reafirmamos el compromiso adquirido en la Agenda 2030 para el Desarrollo Sostenible, en particular el Objetivo de Desarrollo Sostenible (ODS) 4 y sus metas, y hemos analizado los desafíos que afrontan los sistemas de educación y formación para alcanzar el ODS 4. Estamos decididos a promover las respuestas políticas adecuadas para lograr la integración sistemática de la inteligencia artificial y la educación, a fin de innovar la educación, la docencia y el aprendizaje, y para que la inteligencia artificial contribuya a acelerar la consecución de unos sistemas educativos abiertos y flexibles que permitan oportunidades de aprendizaje permanente equitativo, pertinente y de calidad para todos, lo que contribuirá al logro de los ODS y al futuro compartido de la humanidad.

3. Recordando la *Declaración de Qingdao*, aprobada en 2015, sobre el aprovechamiento de las tecnologías de la información y la comunicación (TIC) para lograr el ODS 4, en la que se afirma que las nuevas tecnologías deben aprovecharse para reforzar los sistemas educativos, el acceso a la educación para todos, el aprendizaje efectivo y de calidad y una prestación de servicios equitativa y más eficiente, somos conscientes de la urgencia de reafirmar y renovar este compromiso a medida que avanzamos hacia una era caracterizada por la aplicación generalizada de la inteligencia artificial.

4. Hemos analizado las tendencias recientes en la evolución de la inteligencia artificial y su profundo impacto en las sociedades humanas, las economías y el mercado laboral, así como en la educación y los sistemas de aprendizaje permanente. Hemos examinado las implicaciones de la inteligencia artificial para el futuro del trabajo y el desarrollo de competencias, así como su potencial para reconfigurar los fundamentos básicos de la educación, la docencia y el aprendizaje.

5. Reconocemos la complejidad y el rápido desarrollo del campo de la inteligencia artificial, con sus múltiples interpretaciones, su amplio alcance y sus variadas definiciones, así como la diversidad de sus aplicaciones en diferentes contextos y los desafíos éticos que plantea.

6. Reconocemos también las características distintivas de la inteligencia humana. Recordando los principios enunciados en la *Declaración Universal de Derechos Humanos*, reafirmamos el enfoque humanista de la UNESCO respecto de la utilización de la inteligencia artificial con miras a proteger los derechos humanos y a proporcionar a todas las personas los valores y las competencias necesarios para una colaboración eficaz entre el ser humano y la máquina en la vida, el aprendizaje y el trabajo, y para el desarrollo sostenible.

7. También afirmamos que el desarrollo de la inteligencia artificial debe estar controlado por el ser humano y centrado en las personas; que la implantación de la inteligencia artificial debe estar al servicio de las personas para mejorar las capacidades humanas; que la inteligencia artificial debe concebirse de manera ética, no discriminatoria, equitativa, transparente y verificable; y que el impacto de la inteligencia artificial en las personas y la sociedad debe ser objeto de seguimiento y evaluación a lo largo de las cadenas de valor.

RECOMENDAMOS que los gobiernos y otras partes interesadas de los Estados Miembros de la UNESCO, de conformidad con su legislación, políticas públicas y prácticas, consideren la posibilidad de aplicar las siguientes medidas en respuesta a las oportunidades y los desafíos que presenta la inteligencia artificial en relación con la educación:

Planificación de la inteligencia artificial en las políticas educativas

8. Tener presente el carácter multidisciplinario de la inteligencia artificial y sus impactos; armonizar el uso de la inteligencia artificial en la educación con las políticas públicas, en particular la política educativa; adoptar enfoques a nivel de todo el gobierno, intersectoriales y de múltiples interesados para la planificación y la gobernanza de la inteligencia artificial en la educación; y establecer prioridades estratégicas basadas en los desafíos locales relativos a la consecución del ODS 4 y sus metas, así como de los demás ODS. Planificar y aplicar estrategias coherentes a nivel de todo el sistema para el uso de la inteligencia artificial en la educación que estén armonizadas e integradas con las políticas educativas, dentro de una perspectiva de aprendizaje permanente.

9. Tener presentes las necesidades de inversión para la implantación de la inteligencia artificial en las políticas y los programas educativos. Tener en cuenta los equilibrios entre las diferentes prioridades de las políticas educativas y determinar diferentes fuentes de financiación, incluidos los mecanismos de financiación nacionales (públicos y privados), internacionales e innovadores. Tener en cuenta también el potencial de la inteligencia artificial para combinar y analizar múltiples fuentes de datos a fin de mejorar la eficiencia de la toma de decisiones.

La inteligencia artificial para la gestión y la impartición de la educación

10. Tener en cuenta el gran avance en el uso de los datos para transformar los procesos de planificación de políticas basadas en datos empíricos. Considerar la posibilidad de integrar o elaborar tecnologías y herramientas de inteligencia artificial que sean pertinentes para perfeccionar los sistemas de información sobre la gestión de la educación (EMIS, por sus siglas en inglés) a fin de mejorar la recopilación y el procesamiento de datos, de modo que la gestión y la impartición de la educación sean más equitativas, inclusivas, abiertas y personalizadas.

11. Considerar también la posibilidad de introducir nuevos modelos para impartir educación y formación en diferentes instituciones y entornos de aprendizaje que puedan verse facilitados por el uso de la inteligencia artificial, en beneficio de diferentes interesados, como los estudiantes, el personal docente, los padres y las comunidades.

La inteligencia artificial para apoyar la docencia y a los docentes

12. Tener en cuenta que, si bien la inteligencia artificial ofrece oportunidades para apoyar a los docentes en sus responsabilidades educativas y pedagógicas, la interacción humana y la colaboración entre los docentes y los educandos deben seguir ocupando un lugar esencial en la educación. Tener presente que los docentes no pueden ser desplazados por las máquinas, y velar por que sus derechos y condiciones de trabajo estén protegidos.

13. Revisar y definir dinámicamente las funciones de los docentes y las competencias que necesitan en el contexto de las políticas relativas a los docentes, fortalecer las instituciones de formación de docentes y elaborar programas adecuados de desarrollo de capacidades para preparar a los docentes para trabajar eficazmente en entornos educativos con fuerte presencia de la inteligencia artificial.

La inteligencia artificial para el aprendizaje y la evaluación del aprendizaje

14. Conocer las tendencias en cuanto al potencial de la inteligencia artificial para apoyar el aprendizaje y las evaluaciones del aprendizaje, y revisar y ajustar los planes de estudios para promover la integración profunda de la inteligencia artificial y transformar las metodologías del aprendizaje. Considerar la posibilidad de aplicar las herramientas de inteligencia artificial disponibles o elaborar soluciones de inteligencia artificial innovadoras de modo que los beneficios del uso de la inteligencia artificial superen claramente los riesgos, a fin de facilitar tareas de aprendizaje bien definidas en diferentes áreas temáticas y apoyar la elaboración de herramientas de inteligencia artificial para competencias y aptitudes interdisciplinarias.

15. Apoyar experimentaciones en toda la escuela sobre el uso de la inteligencia artificial para facilitar la innovación en la docencia y el aprendizaje, extrayendo conclusiones de los casos exitosos y ampliando las prácticas basadas en datos empíricos.

16. Aplicar o elaborar herramientas de inteligencia artificial para apoyar los procesos de aprendizaje adaptativo; para aprovechar el potencial de los datos a fin de permitir la evaluación de las múltiples dimensiones de las competencias de los estudiantes; y para apoyar la evaluación a gran escala y a distancia.

Desarrollo de valores y competencias para la vida y el trabajo en la era de la inteligencia artificial

17. Tener presente la transformación sistémica y a largo plazo del mercado laboral, incluida su dinámica de género, debido a la adopción de la inteligencia artificial. Actualizar y elaborar mecanismos y herramientas para prever y determinar las competencias necesarias actualmente y en el futuro en relación con el desarrollo de la inteligencia artificial, a fin de velar por la pertinencia de los planes de estudios respecto a los cambios que afectan a las economías, los mercados laborales y las sociedades. Integrar las competencias relacionadas con la inteligencia artificial en los planes de estudios de las escuelas y en las cualificaciones de la enseñanza y formación técnica y profesional (EFTP) y de la educación superior, teniendo en consideración los aspectos éticos y las disciplinas humanísticas interrelacionadas.

18. Tener en cuenta la aparición de un conjunto de competencias básicas sobre inteligencia artificial necesarias para una colaboración eficaz entre el ser humano y la máquina, sin perder de vista la necesidad de competencias fundamentales como la alfabetización y la aritmética. Adoptar medidas institucionales para mejorar la adquisición de competencias básicas sobre inteligencia artificial en todos los estratos de la sociedad.

19. Establecer planes a medio o largo plazo y adoptar medidas urgentes para apoyar a las instituciones de educación superior y de investigación en la elaboración o la mejora de cursos y programas de investigación para desarrollar el talento local en materia de inteligencia artificial, a fin de contar con un gran número de profesionales locales de la inteligencia artificial que tengan la pericia necesaria para diseñar, programar y elaborar sistemas de inteligencia artificial.

La inteligencia artificial para ofrecer oportunidades de aprendizaje permanente para todos

20. Reafirmar que el principio rector para lograr el ODS 4 es el aprendizaje permanente, que abarca el aprendizaje formal, no formal e informal. Adoptar las plataformas de inteligencia artificial y el análisis del aprendizaje mediante datos como tecnologías clave en la construcción de sistemas integrados de aprendizaje permanente para facilitar el aprendizaje personalizado en cualquier momento, en cualquier lugar y potencialmente para cualquier persona, con respeto por la voluntad de los educandos. Aprovechar el potencial de la inteligencia artificial para posibilitar vías de aprendizaje flexibles y la acumulación, el reconocimiento, la certificación y la transferencia de los resultados del aprendizaje individuales.

21. Tener presente la necesidad de prestar una atención normativa adecuada a las necesidades de las personas mayores, especialmente las mujeres, y de implicarlas en el desarrollo de los valores y las competencias necesarios para convivir con la inteligencia artificial, a fin de romper las barreras para el acceso a la vida digital. Planificar y ejecutar programas con financiación suficiente para dotar a los trabajadores mayores de competencias y opciones que les permitan permanecer económicamente activos durante el tiempo que deseen y participar en sus sociedades.

Promoción del uso equitativo e inclusivo de la inteligencia artificial en la educación

22. Reafirmar que garantizar la inclusión y la equidad en la educación y mediante ella, y ofrecer oportunidades de aprendizaje permanente para

todos, son las piedras angulares para el logro del ODS 4 - Educación 2030. Reafirmar que los avances tecnológicos en el campo de la inteligencia artificial en la educación son una oportunidad para mejorar el acceso a la educación de los grupos más vulnerables.

23. Velar por que la inteligencia artificial promueva oportunidades de educación y aprendizaje de alta calidad para todos, sin distinción por razón de género, discapacidad, condición social o económica, origen étnico o cultural o ubicación geográfica. El desarrollo y el uso de la inteligencia artificial en la educación no deben agravar la brecha digital ni mostrar sesgos contra ningún grupo minoritario o vulnerable.

24. Velar por que las herramientas de inteligencia artificial para la docencia y el aprendizaje permitan la inclusión efectiva de los estudiantes con discapacidades o dificultades de aprendizaje y de quienes estudian en un idioma distinto de su lengua materna.

Inteligencia artificial con equidad de género e inteligencia artificial para la igualdad de género

25. Subrayar que la brecha de género en cuanto a las competencias digitales es una de las causas de la baja proporción de mujeres entre los profesionales de la inteligencia artificial y exacerba las desigualdades de género existentes.

26. Afirmar nuestro compromiso de elaborar aplicaciones de la inteligencia artificial en la educación que estén libres de sesgos de género y de velar por que los datos utilizados para el desarrollo de la inteligencia artificial tengan en cuenta las cuestiones de género. Las aplicaciones de la inteligencia artificial deben impulsar la promoción de la igualdad de género.

27. Promover la igualdad de género en la elaboración de herramientas de inteligencia artificial y dotar a las niñas y mujeres de competencias de inteligencia artificial para promover la igualdad de género en la fuerza laboral y en los empleadores del ámbito de la inteligencia artificial.

Velar por el uso ético, transparente y verificable de los datos y algoritmos educativos

28. Tener en cuenta que las aplicaciones de la inteligencia artificial pueden imponer diferentes tipos de sesgos inherentes a los datos de los que se nutre la tecnología, así como a la forma en que se construyen y utilizan los procesos y algoritmos. Tener en cuenta los dilemas que plantea el equilibrio entre el acceso abierto a los datos y la protección de la privacidad de los datos. Tener presentes las cuestiones legales y los riesgos éticos relacionados con la propiedad y la privacidad de los datos y su disponibilidad para el bien público. Tener presente la importancia de adoptar principios relativos a la ética, la privacidad y la seguridad como parte del diseño.

29. Experimentar y adoptar nuevas tecnologías y herramientas de inteligencia artificial para garantizar la protección de la privacidad de los datos y la seguridad de los datos de docentes y educandos. Apoyar un estudio sólido y a largo plazo de cuestiones éticas más profundas en relación con la inteligencia artificial, velando por que la inteligencia artificial se utilice para el bien y se impidan sus aplicaciones nocivas. Elaborar leyes de protección de datos y marcos regulatorios integrales para garantizar la utilización y reutilización éticas, no discriminatorias, equitativas, transparentes y verificables de los datos de los educandos.

30. Ajustar los marcos regulatorios existentes o adoptar otros nuevos para velar por el desarrollo y el uso responsables de las herramientas de inteligencia artificial para la educación y el aprendizaje. Facilitar la investigación sobre cuestiones relacionadas con la ética y la privacidad y seguridad de los datos de la inteligencia artificial y sobre las preocupaciones por el impacto negativo de la inteligencia artificial en los derechos humanos y la igualdad de género.

Seguimiento, evaluación e investigación

31. Tener presente la falta de estudios sistemáticos sobre los impactos de las aplicaciones de la inteligencia artificial en la educación. Apoyar la

investigación, la innovación y el análisis de los efectos de la inteligencia artificial en las prácticas y los resultados del aprendizaje, así como en la aparición y validación de nuevas formas de aprendizaje. Adoptar un enfoque interdisciplinario para la investigación sobre la aplicación de la inteligencia artificial en la educación. Fomentar la investigación comparativa y la colaboración entre países.

32. Considerar la posibilidad de elaborar mecanismos de seguimiento y evaluación para medir el impacto de la inteligencia artificial en la educación, la docencia y el aprendizaje, a fin de proporcionar una base válida y sólida basada en datos empíricos para la formulación de políticas.

RECOMENDAMOS que las organizaciones internacionales y los asociados que trabajan sobre el terreno consideren la posibilidad de aplicar las siguientes medidas:

Financiación, alianzas y cooperación internacional

33. Supervisar y evaluar el impacto de la brecha y las disparidades entre los países en cuanto al desarrollo de la inteligencia artificial, sobre la base de los datos presentados voluntariamente por los países, y tener en cuenta los riesgos de polarización entre los que tienen acceso a la inteligencia artificial y los que no. Reiterar la importancia de abordar estas preocupaciones, dando especial prioridad a África, los países menos adelantados (PMA), los pequeños Estados insulares en desarrollo (PEID) y los países afectados por conflictos y desastres.

34. Coordinar medidas colectivas para promover el uso equitativo de la inteligencia artificial en la educación en el contexto de la arquitectura mundial y regional de Educación 2030, en particular mediante el intercambio de tecnología, programas y recursos en materia de inteligencia artificial para el desarrollo de capacidades, con el debido respeto a los derechos humanos y la igualdad de género.

35. Apoyar la realización de exámenes prospectivos sobre cuestiones de vanguardia relacionadas con las consecuencias del desarrollo futuro de la inteligencia artificial y facilitar la exploración de estrategias y

prácticas eficaces sobre el uso de la inteligencia artificial para innovar en la educación, con el objetivo de crear una comunidad internacional con puntos de vista comunes sobre la inteligencia artificial y la educación.

36. Adecuar la cooperación internacional a las necesidades nacionales para el desarrollo y el uso de la inteligencia artificial en la educación y para la cooperación intersectorial, con el fin de mejorar la apropiación del desarrollo de la tecnología de la inteligencia artificial entre los profesionales de la inteligencia artificial. Reforzar el intercambio de información y de prácticas prometedoras, así como la coordinación y las medidas complementarias entre los países.

37. Proporcionar plataformas adecuadas para el intercambio internacional de información sobre marcos regulatorios, instrumentos y enfoques en relación con la aplicación de la inteligencia artificial en la educación, en particular mediante la Semana del Aprendizaje Móvil de la UNESCO y a través de otros organismos de las Naciones Unidas, y apoyar y aprovechar de este modo la cooperación Sur-Sur y Norte-Sur-Sur sobre el uso de la inteligencia artificial para el logro del ODS 4.

38. Crear alianzas de múltiples interesados y movilizar recursos para reducir la brecha en materia de inteligencia artificial y aumentar la inversión en la aplicación de la inteligencia artificial en la educación.

INVITAMOS a la Directora General de la UNESCO a que procure poner en práctica las siguientes medidas:

39. Establecer una plataforma sobre "inteligencia artificial para la educación" que sirva de centro de intercambio de información sobre cursos de inteligencia artificial de código abierto, herramientas de inteligencia artificial, ejemplos de integración de la inteligencia artificial en las políticas educativas, marcos regulatorios y mejores prácticas sobre la inteligencia artificial en la educación, con vistas a promover el uso de la inteligencia artificial para el logro del ODS 4, fomentar el debate sobre el futuro de la educación y el aprendizaje y hacer que los recursos y cursos de inteligencia artificial de código abierto sean accesibles para todos.

40. Elaborar directrices y recursos, en consulta con los Estados Miembros, para apoyar la elaboración de políticas y estrategias que permitan una utilización eficaz y equitativa de la inteligencia artificial en la educación. Apoyar el desarrollo de capacidades de los responsables de la formulación de políticas educativas.

41. Reforzar la función rectora de la UNESCO en cuanto al uso de la inteligencia artificial en la educación en todos los sectores, divisiones o departamentos interesados y movilizar los institutos y redes de la Organización.

42. Apoyar la integración de las competencias sobre inteligencia artificial en los marcos de competencias de los docentes en materia de TIC y apoyar a los países en la formación del personal docente para el trabajo en entornos educativos con fuerte presencia de la inteligencia artificial.

43. Seguir ampliando la cooperación de la UNESCO en el ámbito del uso de la inteligencia artificial en la educación con los asociados de las Naciones Unidas y multilaterales pertinentes, así como con los bancos regionales de desarrollo y las organizaciones regionales y con el sector privado.

44. Adoptar medidas apropiadas de seguimiento de la Conferencia en los planos regional e internacional, en cooperación con los asociados para el desarrollo que trabajan en este ámbito, a fin de aprovechar y ampliar el alcance del Consenso.

Организация Объединенных Наций по вопросам образования, науки и культуры

ПЕКИНСКИЙ КОНСЕНСУС по искусственному интеллекту и образованию

Итоговый документ Международной конференции по искусственному интеллекту и образованию

«Планирование образования в эпоху искусственного интеллекта: задать направление технологическому прорыву»

16-18 мая 2019 г. Пекин, Китайская Народная Республика

РУССКИЙ

Сектор образования ЮНЕСКО
В силу того, что образование является одним из основных прав человека, фундаментом укрепления мира и фактором устойчивого развития, ЮНЕСКО рассматривает это направле-ние деятельности в качестве своей первостепенной задачи. ЮНЕСКО является специализи-рованным учреж¬дением Организации Объединенных Наций, а ее Сектор образования обес-печивает руководящую роль в своей области на глобальном и региональном уровнях, содей-ствует укреплению национальных систем образования и предпринимает шаги, связанные с реагированием на глобальные проблемы современности, используя для этого в качестве инструмента образование и уделяя особое внимание вопросам равенства мужчин и женщин и проблематике стран Африки.

Глобальная повестка дня в области образования на период до 2030 года
ЮНЕСКО как специализированному учреждению Организации Объединенных Наций в обла-сти образования было поручено руководство и координация деятельности, связанной с осу-ществлением повестки дня «Образование-2030», которая является частью глобальных уси-лий по искоренению к 2030 году нищеты посредством реализации 17 целей в области устой-чивого развития. Образованию, имеющему важнейшее значение для достижения всех этих целей, посвящена отдельная цель – Цель 4, направленная на «***обеспечение всеохватного и справедливого качественного образования и поощрение возможности обучения на протяже-нии всей жизни для всех***».
В рамочной программе действий «Образование-2030» сформули-рованы руководящие принципы в отношении осуществления этой амбициозной цели и обяза-тельства государств в этой области.

UNESCO
Организация Объединенных Наций по вопросам образования, науки и культуры

Сектор образования

ОБРАЗОВАНИЕ 2030

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Преамбула

1. Мы, участники *Международной конференции по искусственному интеллекту (ИИ) и образованию*, включая 50 государственных министров и заместителей министров, около 500 международных делегатов из более чем 100 государств-членов, учреждений Организации Объединенных Наций, научных институтов, гражданского общества и частного сектора, собрались в Пекине, Китайская Народная Республика, 16-18 мая 2019 г. Мы выражаем искреннюю признательность ЮНЕСКО и правительству Китайской Народной Республики за совместную организацию конференции и муниципалитету Пекина за теплый прием и радушное гостеприимство.

2. Мы вновь подтвердили приверженность, отраженную в Повестке дня в области устойчивого развития на период до 2030 года, в частности в цели 4 в области устойчивого развития (ЦУР 4) и ее задачах, и обсудили проблемы, с которыми сталкиваются системы образования и профессиональной подготовки в работе по ЦУР 4. Мы преисполнены решимости руководить разработкой надлежащих политических мер, направленных на систематическую интеграцию искусственного интеллекта и образования в целях внедрения инноваций в процессы образования, преподавания и обучения, а также на использование потенциала ИИ для ускорения создания открытых и гибких систем образования, предоставляющих всем людям справедливые, надлежащие и качественные возможности обучения на протяжении всей жизни, что будет способствовать достижению ЦУР и общему будущему человечества.

3. Ссылаясь на принятую в 2015 г. *декларацию Циндао* об использовании информационно-коммуникационных технологий (ИКТ) для достижения ЦУР 4, в которой говорится о необходимости задействовать потенциал новых технологий для укрепления систем образования, обеспечения доступа к образованию для всех, качественного и эффективного обучения и справедливого и более эффективного предоставления услуг, мы осознаем настоятельную необходимость подтверждения и актуализации этой приверженности, поскольку мы вступаем в эпоху повсеместного применения ИИ.

4. Мы рассмотрели последние тенденции развития ИИ и его глубокое воздействие на человеческое общество, экономику и рынок труда, а также на системы образования и обучения на протяжении всей жизни. Мы изучили влияние ИИ на перспективы занятости и развития навыков и рассмотрели использование его потенциала для пересмотра основных принципов образования, преподавания и обучения.

5. Мы признаем сложность и стремительное развитие сферы искусственного интеллекта, который имеет множество толкований, отличается широким спектром и разнообразием определений, а также разнообразием возможностей его применения в различных условиях и связанных с ним этических проблем.

6. Мы также признаем отличительные особенности человеческого интеллекта. Ссылаясь на принципы, изложенные во *Всеобщей декларации прав человека*, мы подтверждаем гуманистический подход ЮНЕСКО к использованию ИИ в целях защиты прав человека и развития у всех людей соответствующих ценностей и навыков, необходимых для эффективного взаимодействия человека и машины в повседневной жизни, в процессе обучения и работы, а также для устойчивого развития.

7. Мы также подтверждаем, что развитие ИИ должно осуществляться под контролем человека и быть ориентировано на людей, что развертывание ИИ должно отвечать интересам людей и способствовать укреплению их потенциала, что разработка ИИ должна руководствоваться принципами этики, справедливости, транспарентности и подотчетности и отказа от дискриминации и что воздействие ИИ на людей и общество должно контролироваться и оцениваться на всех этапах производственно-сбытовой цепочки.

МЫ РЕКОМЕНДУЕМ правительствам и другим заинтересованным сторонам в государствах – членах ЮНЕСКО рассмотреть в соответствии с их законодательством, государственной политикой и практикой вопрос о принятии следующих мер в ответ на связанные с ИИ возможности и проблемы в сфере образования:

Планирование ИИ в образовательной политике

8. Учитывать междисциплинарный характер ИИ и его воздействие; согласовывать использование ИИ в сфере образования с государственной политикой, в частности с политикой в области образования; применять общегосударственные, межсекторальные и многосторонние подходы к планированию и управлению использованием ИИ в сфере образования; определить стратегические приоритеты с учетом местных проблем в достижении ЦУР 4 и решении ее задач, а также других ЦУР. Планировать и разрабатывать последовательные общесистемные стратегии применения ИИ в сфере образования, согласованные с политикой в области образования и являющиеся ее составной частью, в рамках концепции обучения на протяжении всей жизни.

9. Учитывать потребности в инвестициях для включения ИИ в политику и программы в области образования. Обеспечить должный баланс различных приоритетов политики в области образования и определить различные источники финансирования, включая национальные (государственные и частные), международные и инновационные механизмы финансирования. Рассмотреть возможности ИИ в области комбинирования и анализа многочисленных источников данных в целях повышения эффективности процесса принятия решений.

Использование ИИ в области образования и управления им

10. Принимать во внимание прорыв в использовании данных при преобразовании процессов планирования политики, основанных на фактических данных. Рассмотреть вопрос об интеграции или разработке технологий и инструментов на основе ИИ, которые можно

использовать для модернизации информационных систем управления образованием (ИСУО) в целях совершенствования сбора и обработки данных, организации более справедливого, инклюзивного, открытого и индивидуализированного образования и управления им.

11. Рассмотреть также возможность внедрения новых моделей образования и профессиональной подготовки на основе ИИ в различных учебных заведениях и структурах и в интересах различных субъектов, таких как учащиеся, преподавательский состав, родители и сообщества.

Использование ИИ в процессе преподавания и в интересах расширения прав и возможностей учителей

12. Принимать во внимание, что несмотря на предоставляемые ИИ возможности для поддержки учителей в выполнении ими образовательных и педагогических обязанностей, личное взаимодействие и совместная работа учителей и учащихся должны оставаться центральным элементом образования. Понимать, что учителей невозможно заменить машинами, и обеспечивать защиту их прав и условий труда.

13. Определить и оперативно пересматривать функции учителей и необходимые им компетенции в рамках политики в отношении учителей, укреплять педагогические учебные заведения и разрабатывать соответствующие программы по наращиванию потенциала для подготовки учителей к эффективной работе в условиях широкого применения ИИ в сфере образования.

Использование ИИ в процессе обучения и для оценки успеваемости

14. Принимать во внимание тенденции, касающиеся использования ИИ в процессе обучения и для проведения оценок успеваемости, пересмотреть и скорректировать учебные программы в целях содействия углубленному включению ИИ, и преобразованию учебных методик. Рассмотреть вопрос о применении имеющихся инструментов на

основе ИИ или разработке инновационных решений в области ИИ в случаях, когда преимущества использования ИИ очевидно перевешивают риски, для содействия четкому определению учебных задач в различных предметных областях и поддержки разработки инструментов на основе ИИ для развития междисциплинарных навыков и компетенций.

15. Оказывать поддержку проведению общешкольных экспериментальных тестов использования ИИ в целях содействия инновациям в процессе преподавания и обучения, извлекая уроки из успешных примеров и расширяя масштабы применения научно обоснованного передового опыта.

16. Применять или разрабатывать инструменты на основе ИИ для поддержки адаптивных процессов обучения; использовать потенциал данных для оценки различных аспектов компетенций учащихся; поддерживать проведение крупномасштабной и дистанционной оценки.

Развитие ценностей и навыков, необходимых для жизни и работы в эпоху ИИ

17. Учитывать системные и долгосрочные преобразования на рынке труда, включая его гендерную динамику, в результате внедрения ИИ. Модернизировать и развивать механизмы и инструменты для прогнозирования и определения текущих и будущих потребностей в навыках в связи с развитием ИИ, с тем чтобы обеспечить актуальность учебных программ для меняющейся экономики, рынков труда и общества. Включить связанные с ИИ навыки в учебные школьные программы и программы квалификации технического и профессионального образования и подготовки (ТПОП), а также высшего образования, с учетом этических аспектов и взаимосвязанных гуманитарных дисциплин.

18. Наблюдать за формированием комплекса навыков грамотности в области ИИ, необходимых для эффективного взаимодействия между человеком и машиной, не забывая при этом о необходимости развития базовых навыков, таких как грамотность и счет. Принимать

институциональные меры по повышению уровня грамотности в области ИИ среди всех категорий общества.

19. Разработать среднесрочные или долгосрочные планы и принять срочные меры по оказанию поддержки высшим учебным заведениям и научно-исследовательским институтам в разработке или совершенствовании курсов и исследовательских программ по подготовке местных специалистов в области ИИ в целях создания обширного резерва местных специалистов по ИИ, обладающих опытом разработки, программирования и развития систем на основе ИИ.

Использование ИИ для предоставления возможностей обучения на протяжении всей жизни для всех

20. Подтвердить, что руководящим принципом для достижения ЦУР 4 является обучение на протяжении всей жизни, которое охватывает формальное, неформальное и информальное обучение. Использовать платформы ИИ и методы обучения на основе данных в качестве ключевых технологий для создания комплексных систем обучения на протяжении всей жизни, позволяющих организовать индивидуальный процесс обучения в любое время, в любом месте и в перспективе для всех, с учетом способности учащихся действовать самостоятельно. Использовать потенциал ИИ для развития гибких форматов обучения и процессов накопления, признания и сертификации индивидуальных результатов обучения и передачи данных о них.

21. Помнить о необходимости уделять надлежащее политическое внимание потребностям пожилых людей, особенно пожилых женщин, и вовлекать их в процесс формирования ценностей и навыков, необходимых для использования ИИ в повседневной жизни и преодоления барьеров на пути к построению цифрового общества. Планировать и реализовывать подкрепленные достаточным финансированием программы обучения пожилых работников навыкам, которые предоставят им возможность оставаться экономически активными субъектами столько, сколько они пожелают, и участвовать в жизни общества.

Содействие равноправному и инклюзивному использованию ИИ в сфере образования

22. Подтвердить, что соблюдение принципа инклюзивности и справедливости в процессе и посредством образования, а также предоставление возможностей обучения на протяжении всей жизни для всех являются основополагающими элементами достижения ЦУР 4 Образование - 2030. Подтвердить, что технологические достижения, касающиеся применения ИИ в сфере образования, открывают возможности для расширения доступа к образованию для наиболее уязвимых групп населения.

23. Обеспечить, чтобы ИИ способствовал расширению возможностей высококачественного образования и обучения для всех независимо от пола, инвалидности, социально-экономического положения, этнического или культурного происхождения или местонахождения. Развитие и использование ИИ в сфере образования не должно углублять цифровой разрыв, недопустимо также предвзятое отношение к меньшинствам или уязвимым группам.

24. Обеспечить, чтобы используемые при преподавании и обучении инструменты на основе ИИ способствовали эффективной интеграции учащихся, испытывающих трудности в обучении, или учащихся с ограниченными возможностями, а также тех, кто обучается на неродном языке.

Гендерное равноправие в сфере ИИ и использование ИИ для обеспечения гендерного равенства

25. Обратить внимание на то, что гендерный разрыв в цифровых навыках является причиной низкой численности женщин среди специалистов по ИИ и усугубляет существующее гендерное неравенство.

26. Заявить о приверженности разработке гендерно нейтральных приложений ИИ в сфере образования и обеспечению учета гендерных аспектов в данных, используемых для разработки ИИ. Применение ИИ должно стимулировать поощрение гендерного равенства.

27. Поощрять обеспечение гендерного равенства при разработке инструментов на основе ИИ и расширять права и возможности девочек и женщин с помощью навыков работы с ИИ в целях содействия гендерному равенству среди работников и работодателей в сфере ИИ.

Обеспечение этичного, прозрачного и подотчетного использования данных и алгоритмов, касающихся образования

28. Учитывать, что приложения на основе ИИ могут навязывать различные виды предвзятого отношения, если оно заложено в данных, используемых в качестве исходных и для «обучения» этой технологии, а также в способах построения и использования процессов и алгоритмов. Помнить о необходимости поиска баланса между открытым доступом к данным и защитой конфиденциальности данных. Учитывать юридические вопросы и этические риски, связанные с владением данными, конфиденциальностью данных и обеспечением доступа к ним для общественного блага. Понимать важность применения по умолчанию в сфере ИИ принципов этики, конфиденциальности и безопасности.

29. Тестировать и внедрять новые технологии и инструменты на основе ИИ для обеспечения защиты конфиденциальности и безопасности данных учителей и учащихся. Поддерживать серьезные и долгосрочные исследования более глубоких этических проблем в области ИИ, обеспечивая использование ИИ на благо людей и предотвращая его применение в пагубных целях. Разработать всеобъемлющие законы о защите данных и нормативно-правовую базу, гарантирующую этичное, недискриминационное, справедливое, прозрачное и проверяемое использование и переработку данных учащихся.

30. Скорректировать существующие или принять новые нормативно-правовые рамки для обеспечения ответственной разработки и использования инструментов на основе ИИ в области образования и обучения. Содействовать проведению исследований, связанных с этикой ИИ, конфиденциальностью и безопасностью данных, а также

с обеспокоенностью по поводу негативного воздействия ИИ на права человека и гендерное равенство.

Мониторинг, оценка и исследования

31. Принимать во внимание нехватку систематических исследований о воздействии применения ИИ в сфере образования. Оказывать поддержку научным исследованиям, инновациям и анализу воздействия ИИ на практические методы обучения и его результаты, а также на появление и утверждение новых форм обучения. Применять междисциплинарный подход к исследованиям, касающимся использования ИИ в сфере образования. Поощрять сравнительные межстрановые исследования и сотрудничество.

32. Рассмотреть вопрос о разработке механизмов мониторинга и оценки для измерения воздействия ИИ на образование, преподавание и обучение, с тем чтобы сформировать надежную и функциональную фактологически обоснованную основу для разработки политики.

МЫ РЕКОМЕНДУЕМ международным организациям и партнерам, работающим в данной области, рассмотреть возможность принятия следующих мер:

Финансирование, партнерские связи и международное сотрудничество

33. Проводить мониторинг и оценку воздействия разрыва в области использования ИИ и различий в уровне развития ИИ между странами на основе добровольно представляемых ими данных и учитывать риски их разделения на два противоположных лагеря: тех, кто имеет доступ к ИИ, и тех, кто такого доступа не имеет. Подтвердить важность решения этих проблем, уделяя при этом особое внимание Африке, наименее развитым странам (НРС), малым островным развивающимся государствам (МОСРГ) и странам, пострадавшим в результате конфликтов и бедствий.

34. Координировать коллективную деятельность, направленную на содействие справедливому использованию ИИ в сфере образования в контексте глобальной и региональной архитектуры повестки «Образование - 2030», в том числе посредством совместного использования технологий, программ и ресурсов ИИ в целях создания потенциала при должном уважении прав человека и гендерного равенства.

35. Оказывать поддержку перспективным обзорам смежных вопросов, связанных с последствиями развития новых форм ИИ, и содействовать изучению эффективных стратегий и практических методов использования ИИ для внедрения инноваций в сфере образования с целью формирования международного сообщества единомышленников в области ИИ и образования.

36. Согласовывать международное сотрудничество с национальными потребностями в области разработки и использования ИИ в сфере образования, а также в области межсекторального сотрудничества в целях повышения приверженности специалистов по ИИ разработке технологий ИИ. Повышать эффективность обмена информацией и перспективными методами, а также укреплять координацию и взаимодополняемость действий между странами.

37. Предоставлять надлежащие платформы для международного обмена информацией о нормативных рамках, инструментах и подходах к использованию ИИ в области образования, в том числе в рамках Недели мобильного обучения ЮНЕСКО и через другие учреждения системы ООН, и оказывать тем самым поддержку сотрудничеству по линии Юг-Юг и Север-Юг-Юг и использовать его преимущества для того, чтобы задействовать потенциал ИИ для достижения ЦУР 4.

38. Налаживать многосторонние партнерские связи и привлекать ресурсы для сокращения разрыва в области ИИ и наращивания инвестиций в использование ИИ в сфере образования.

МЫ ПРЕДЛАГАЕМ Генеральному директору ЮНЕСКО добиваться принятия следующих мер:

39. Создать платформу «ИИ в интересах образования», которая будет работать в качестве центра обмена информацией о находящихся в открытом доступе курсах по ИИ, инструментах на основе ИИ, примерах учета ИИ в политике и нормативных положениях, касающихся образования, а также о передовом опыте использования ИИ в сфере образования, с целью содействия использованию ИИ для достижения ЦУР 4, поддержки дискуссий о перспективах образования и обучения и обеспечения всеобщего доступа к открытым ресурсам и курсам по ИИ.

40. Разработать в консультации с государствами-членами руководящие принципы и ресурсы для поддержки разработки политики и стратегий эффективного и равноправного использования ИИ в сфере образования. Оказывать поддержку укреплению потенциала лиц, ответственных за разработку политики в области образования.

41. Укреплять ведущую роль ЮНЕСКО в отношении использования ИИ в сфере образования во всех соответствующих секторах, отделах или департаментах и привлекать к этой работе институты и сети Организации.

42. Оказывать поддержку включению навыков использования ИИ в рамки компетентности в области ИКТ для учителей и помогать странам в подготовке преподавательского состава к работе в условиях активного использования ИИ в сфере образования.

43. Продолжать расширять сотрудничество ЮНЕСКО с соответствующими учреждениями Организации Объединенных Наций и многосторонними партнерами, а также с региональными банками и организациями развития и частным сектором по тематике использования ИИ в сфере образования.

44. Принимать на региональном и международном уровнях надлежащие меры по итогам Конференции, действуя в сотрудничестве с работающими в этой области партнерами по развитию, с опорой на настоящий Консенсус и в целях расширения сферы его охвата.

联合国教育、
科学及文化组织

人工智能与教育
北京共识

国际人工智能与教育大会成果文件

“规划人工智能时代的教育：引领与跨越”

2019年5月16 – 18日　中华人民共和国　北京

中文

教科文组织教育部门

教育是教科文组织工作的重中之重，它既是一项基本人权，也是建设和平和推动可持续发展的基础。教科文组织是主管教育的联合国专门机构，其教育部门在全球和地区的教育领域发挥领导作用，致力于加强各国教育体系并通过教育应对当今的全球挑战，尤为重视性别平等和非洲。

2030年全球教育议程

教科文组织作为主管教育的联合国专门机构，负责领导并协调2030年教育议程——旨在通过17项可持续发展目标在2030年前消除贫穷的全球运动的一部分。教育既是实现各项可持续发展目标的关键，同时自身也是单独一项目标（可持续发展目标4），即“确保包容和公平的优质教育，让全民终身享有学习机会”。《2030年教育行动框架》为落实这一宏伟目标及各项承诺提供了指导方针。

UNESCO 联合国教育、科学及文化组织

教育部门

2030年教育

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序言

1. 我们——国际人工智能与教育大会与会者，包括50名政府部长和副部长、来自100多个会员国以及联合国机构、学术机构、民间社会和私营部门的约500名代表，于2019年5月16–18日齐聚中国北京。我们衷心感谢联合国教育、科学及文化组织和中华人民共和国政府合作举办此次大会，以及北京市政府的热情欢迎和盛情款待。

2. 我们重申了《2030年可持续发展议程》中的承诺，特别是可持续发展目标4及其各项具体目标，并讨论了教育和培训系统在实现可持续发展目标4时所面临的挑战。我们致力于引领实施适当的政策应对策略，通过人工智能与教育的系统融合，全面创新教育、教学和学习方式，并利用人工智能加快建设开放灵活的教育体系，确保全民享有公平、适合每个人且优质的终身学习机会，从而推动可持续发展目标和人类命运共同体的实现。

3. 我们回顾2015年通过的关于利用信息通信技术（信通技术）实现可持续发展目标4的《青岛宣言》，其中指出必须利用新兴技术强化教育体系、拓展全民受教育机会、提高学习质量和效果以及强化公平和更高效的教育服务供给；当我们步入人工智能广泛应用的时代时，我们认识到重申并更新这一承诺的迫切需要。

4. 我们研究了人工智能演变的最新趋势及其对人类社会、经济和劳动力市场以及教育和终身学习体系的深远影响。我们审视了人工智能对于未来工作和技能培养的潜在影响，并探讨了其在重塑教育、教学和学习的核心基础方面的潜力。

5. 我们认识到人工智能领域的复杂性和迅猛发展速度、对人工智能的多元化理解、宽泛的外延和各种差异较大的定义、以及在不同场景中的多样化应用及其引发的伦理挑战。

6. 我们还认识到人类智能的独特性。忆及《世界人权宣言》中确立的原则，我们重申联合国教科文组织在人工智能使用方面的人文主义取向，以期保护人权并确保所有人具备在生活、学习和工作中进行有效人机合作以及可持续发展所需的相应价值观和技能。

7. 我们还申明，人工智能的开发应当为人所控、以人为本；人工智能的部署应当服务于人并以增强人的能力为目的；人工智能的设计应合乎伦理、避免歧视、公平、透明和可审核；应在整个价值链全过程中监测并评估人工智能对人和社会的影响。

我们建议，联合国教科文组织会员国政府及其他利益攸关方根据其法律、公共政策和公共惯例，考虑实施以下行动，应对人工智能带来的相关教育机遇和挑战：

规划教育人工智能政策

8. 认识到人工智能的多学科特性及其影响；确保教育人工智能与公共政策特别是教育政策有机配合；采取政府全体参与、跨部门整合和多方协作的方法规划和治理教育人工智能政策；根据本地在实现可持续发展目标4及其具体目标以及其他可持续发展目标的工作中遇到的挑战，确定政策的战略优先领域。从终身学习的角度规划并制定与教育政策接轨和有机协调的全系统教育人工智能战略。

9. 意识到推行教育人工智能政策和工程的巨大投资需求。审慎权衡不同教育政策重点之间的优先级，确定不同的筹资渠道，包括国家经费（公共和私人）、国际资金和创新性的筹资机制。还要考虑到人工智能在合并和分析多个数据来源从而提高决策效率方面的潜力。

人工智能促进教育的管理和供给

10. 意识到应用数据变革基于实证的政策规划方面的突破。考虑整合或开发合适的人工智能技术和工具对教育管理信息系统（EMIS）进行升级换代，以加强数据收集和处理，使教育的管理和供给更加公平、包容、开放和个性化。

11. 还考虑在不同学习机构和学习场境中引入能够通过运用人工智能实现的新的教育和培训供给模式，以便服务于学生、教职人员、家长和社区等不同行为者。

人工智能赋能教学和教师

12. 注意到虽然人工智能为支持教师履行教育和教学职责提供了机会，但教师和学生之间的人际互动和协作应确保作为教育的核心。意识到教师无法被机器取代，应确保他们的权利和工作条件受到保护。

13. 在教师政策框架内动态地审视并界定教师的角色及其所需能力，强化教师培训机构并制定适当的能力建设方案，支持教师为在富含人工智能的教育环境中有效工作做好准备。

人工智能促进学习和学习评价

14. 认识到人工智能在支持学习和学习评价潜能方面的发展趋势，评估并调整课程，以促进人工智能与学习方式变革的深度融合。在使用人工智能的惠益明显大于其风险的领域，考虑应用现有的人工智能工具或开发创新性人工智能解决方案，辅助不同学科领域中明确界定的学习任务，并为开发跨学科技能和能力所需的人工智能工具提供支持。

15. 支持采用全校模式围绕利用人工智能促进教学和学习创新开展试点测试，从成功案例中汲取经验并推广有证据支持的实践模式。

16. 应用或开发人工智能工具以支持动态适应性学习过程；发掘数据潜能，支持学生综合能力的多维度评价；支持大规模远程评价。

培养人工智能时代生活和工作所需的价值观和技能

17. 注意到采用人工智能所致的劳动力市场的系统性和长期性变革，包括性别平等方面的动态。更新并开发有效机制和工具，以预测并确认当前和未来人工智能发展所引发的相关技能需求，以便确保课程与不断变化的经济、劳动力市场和社会相适应。将人工智能相关技能纳入中小学学校课程和职业技术教育与培训（TVET）以及高等教育的资历认证体系中，同时考虑到伦理层面以及相互关联的人文学科。

18. 认识到进行有效的人机协作需要具备一系列人工智能素养，同时不能忽视对识字和算术等基本技能的需求。采取体制化的行动，提高社会各个层面所需的基本人工智能素养。

19. 制定中长期规划并采取紧急行动，支持高等教育及研究机构开发或加强课程和研究项目，培养本地人工智能高端人才，以期建立一个具备人工智能系统设计、编程和开发的大型本地人工智能专业人才库。

人工智能服务于提供全民终身学习机会

20. 重申终身学习是实现可持续发展目标4的指导方针，其中包括正规、非正规和非正式学习。采用人工智能平台和基于数据的学习分析等关键技术构建可支持人人皆学、处处能学、时时可学的综合型终身学习体系，同时尊重学习者的能动性。开发人工智能在促进灵活的终身学习途径以及学习结果累积、承认、认证和转移方面的潜力。

21. 意识到需要在政策层面对老年人尤其是老年妇女的需求给予适当关注，并使他们具备人工智能时代生活所需的价值观和技能，以便为数字化生活消除障碍。规划并实施有充足经费支持的项目，使较年长的劳动者具备技能和选择，能够随自己所愿保持在经济上的从业身份并融入社会。

促进教育人工智能应用的公平与包容

22. 重申确保教育领域的包容与公平以及通过教育实现包容与公平，并为所有人提供终身学习机会，是实现可持续发展目标4—2030年教育的基石。重申教育人工智能方面的技术突破应被视为改善最弱势群体受教育机会的一个契机。

23. 确保人工智能促进全民优质教育和学习机会，无论性别、残疾状况、社会和经济条件、民族或文化背景以及地理位置如何。教育人工智能的开发和使用不应加深数字鸿沟，也不能对任何少数群体或弱势群体表现出偏见。

24. 确保教学和学习中的人工智能工具能够有效包容有学习障碍或残疾的学生，以及使用非母语学习的学生。

性别公平的人工智能和应用人工智能促进性别平等

25. 强调数字技能方面的性别差距是人工智能专业人员中女性占比低的原因之一，且进一步加剧了已有的性别不平等现象。

26. 申明我们致力于在教育领域开发不带性别偏见的人工智能应用程序，并确保人工智能开发所使用的数据具有性别敏感性。同时，人工智能应用程序应有利于推动性别平等。

27. 在人工智能工具的开发中促进性别平等，通过提升女童和妇女的人工智能技能增强她们的权能，在人工智能劳动力市场和雇主中推动性别平等。

确保教育数据和算法使用合乎伦理、透明且可审核

28. 认识到人工智能应用程序可能带有不同类型的偏见，这些偏见是训练人工智能技术所使用和输入的数据自身所携带的以及流程和算法的构建和使用方式中所固有的。认识到在数据开放获取和数据隐私保护之间的两难困境。注意到与数据所有权、数据隐私和服务于公共利益的数据可用性相关的法律问题和伦理风险。注意到采纳合乎伦理、注重隐私和通过设计确保安全等原则的重要性。

29. 测试并采用新兴人工智能技术和工具，确保教师和学习者的数据隐私保护和数据安全。支持对人工智能领域深层次伦理问题进行稳妥、长期的研究，确保善用人工智能，防止其有害应用。制定全面的数据保护法规以及监管框架，保证对学习者的数据进行合乎伦理、非歧视、公平、透明和可审核的使用和重用。

30. 调整现有的监管框架或采用新的监管框架，以确保负责任地开发和使用用于教育和学习的人工智能工具。推动关于人工智能伦理、数据隐私和安全相关问题，以及人工智能对人权和性别平等负面影响等问题的研究。

监测、评估和研究

31. 注意到缺乏有关人工智能应用于教育所产生影响的系统性研究。支持就人工智能对学习实践、学习成果以及对新学习形式的出现和验证产生的影响开展研究、创新和分析。采取跨学科办法研究教育领域的人工智能应用。鼓励跨国比较研究及合作。

32. 考虑开发监测和评估机制，衡量人工智能对教育、教学和学习产生的影响，以便为决策提供可靠和坚实的证据基础。

我们建议活跃在这一领域的国际组织和伙伴考虑实施下列行动：

筹资、伙伴关系和国际合作

33. 基于各国自愿提交的数据，监测并评估各国之间人工智能鸿沟和人工智能发展不平衡现象，并且注意到能够获取使用和开发人工智能和无法使用人工智能的国家之间两极分化的风险。重申解决这些忧虑的重要性，并特别优先考虑非洲、最不发达国家、小岛屿发展中国家以及受冲突和灾害影响的国家。

34. 在“2030年教育”的全球和地区架构范围内，协调集体行动，通过分享人工智能技术、能力建设方案和资源等途径，促进教育人工智能的公平使用，同时对人权和性别平等给予应有的尊重。

35. 支持对与新兴人工智能发展影响相关的前沿问题进行前瞻性研究，推动探索利用人工智能促进教育创新的有效战略和实践模式，以期构建一个在人工智能与教育问题上持有共同愿景的国际社会。

36. 确保国际合作有机配合各国在教育人工智能开发和使用以及跨部门合作方面的需求，以便加强人工智能专业人员在人工智能技术开发方面的自主性。加强信息共享和有良好前景应用模式的交流，以及各国之间的协调和互补协作。

37. 通过联合国教科文组织移动学习周等方式并借助其他联合国机构，为各国之间交流有关教育人工智能领域的监管框架、规范文本和监管方式提供适当的平台，从而支持在发掘人工智能潜力促进可持续发展目标4方面开展南南合作和北南南合作，并从中受益。

38. 建立多利益攸关方伙伴关系并筹集资源，以便缩小人工智能鸿沟，增加对教育人工智能领域的投资。

我们请联合国教科文组织总干事努力实施下列行动：

39. 建立一个“人工智能服务于教育”的平台，作为开源人工智能课程、人工智能工具、教育人工智能政策实例、监管框架和最佳做法的信息交流中心，以期推动利用人工智能促进可持续发展目标4，支持就教育和学习的未来开展辩论，并使开源人工智能资源和课程向所有人开放。

40. 在与会员国开展咨询的基础上制定教育人工智能指导纲要并开发资源，以支持会员国制定促进教育领域有效和公平应用人工智能的政策和战略。支持对教育政策制定者的相关能力建设。

41. 通过强化相关部门及处室并动员联合国教科文组织的机构和网络，加强联合国教科文组织在教育人工智能领域的引领作用。

42. 支持将人工智能技能纳入教师信通技术能力框架，支持各国就教职人员如何在富含人工智能的教育环境下工作开展培训。

43. 在教育人工智能方面，进一步扩大联合国教科文组织与相关联合国机构和多边合作伙伴、地区开发银行和组织以及私营部门的合作。

44. 此次大会之后，采取适当的地区和国际性后续行动，与活跃在这一领域的发展伙伴合作，巩固并扩大本共识的影响。

منظمة الأمم المتحدة
للتربية والعلم والثقافة

توافق بيجين بشأن
الذكاء الاصطناعي والتعليم

الوثيقة الختامية للمؤتمر الدولي للذكاء الاصطناعي والتعليم

«التخطيط التربوي في عصر الذكاء الاصطناعي: ريادة التقدم في مجال التعليم»

١٦-١٨ أيّار/مايو ٢٠١٩، بيجين، جمهورية الصين الشعبية

العربية

قطاع التربية في اليونسكو

تعتبر اليونسكو التربية والتعليم الأولوية الكبرى للمنظمة، إذ يندرج التعليم في عِداد حقوق الإنسان الأساسية ويرسي القواعد اللازمة لبناء السلام وتحقيق التنمية المستدامة. واليونسكو هي وكالة الأمم المتحدة المتخصصة المعنية بالتربية والتعليم. ويتولى قطاع التربية في اليونسكو ريادة المساعي العالمية والإقليمية في مجال التعليم، وتعزيز النُظم التعليمية الوطنية، والتصدي للتحديات العالمية المعاصرة عن طريق التعليم، مع التركيز على المساواة بين الجنسين وعلى أفريقيا.

جدول الأعمال العالمي للتعليم حتى عام 2030

لقد عُهد إلى اليونسكو، بصفتها وكالة الأمم المتحدة المتخصصة المعنية بالتربية والتعليم، بريادة وتنسيق جدول أعمال التعليم حتى عام 2030. ويندرج جدول أعمال التعليم حتى عام 2030 في إطار المساعي العالمية الرامية إلى القضاء على الفقر عن طريق تحقيق 17 هدفاً للتنمية المستدامة بحلول عام 2030. ولا يمكن تحقيق أي هدف من أهداف التنمية المستدامة السبعة عشر بدون التعليم. وتشتمل هذه الأهداف على هدف خاص بالتعليم، وهو الهدف 4 الذي يرمي إلى ***"ضمان التعليم الجيد المنصف والشامل للجميع وتعزيز فرص التعلّم مدى الحياة للجميع"***. ويقدم إطار العمل الخاص بالتعليم حتى عام 2030 الإرشادات اللازمة لتحقيق هذا الهدف النبيل والالتزام بالتعهدات الطموحة التي ينطوي عليها.

قطاع التربية

منظمة الأمم المتحدة
للتربية والعلم والثقافة

التعليم 2030

صدر في عام 2019 عن منظمة الأمم المتحدة للتربية والعلم والثقافة (اليونسكو).
7, place de Fontenoy, 75352 Paris 07 SP, France

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لمزيد من المعلومات، الرجاء التواصل مع
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https://en.unesco.org/themes/ict-education

سيتم تصحيح أي أخطاء أو حذف تم العثور عليه بعد الطباعة في الإصدار عبر الإنترنت على
https://unesdoc.unesco.org/ark:/48223/pf0000368303

الديباجة

١ - نحن المشاركين في المؤتمر الدولي للذكاء الاصطناعي والتعليم، وممثّا ٥٠ وزيراً ونواب الوزراء كذلك حوالي ٥٠٠ ممثل لأكثر من ١٠٠ دولة من الدول الأعضاء الأمم المتحدة والمؤسسات الأكاديمية والمجتمع المدني والقطاع الخاص، قد اجتمعنا بمدينة بيجين في جمهورية الصين الشعبية خلال الفترة الممتدة من ١٦ إلى ١٨ أيّار/مايو ٢٠١٩. وإننا لنعرب عن جزيل شكرنا لليونسكو وحكومة جمهورية الصين الشعبية على اشتراكهما في تنظيم المؤتمر، وعلى ما أبدته سلطات بلدية بيجين من ترحيب حار وكرم ضيافة.

٢ - وقد أكدنا مجدداً التزامنا بما تعهدنا به من قبل في خطة التنمية المستدامة لعام ٢٠٣٠، ولا سيّما بهدف التنمية المستدامة ٤ وغاياته، وبحثنا المصاعب التي تواجهها نُظم التعليم والتدريب في مجال السعي إلى تحقيق هدف التنمية المستدامة ٤. ونتعهد باتخاذ التدابير اللازمة لوضع السياسات الرامية إلى الجمع بطريقة منهجية بين الذكاء الاصطناعي والتعليم من أجل التجديد والابتكار في ميادين التعليم والتدريس والتعلم، وكذلك السياسات الرامية إلى تسخير الذكاء الاصطناعي لتسريع وتيرة العمل على إنشاء نُظم مفتوحة ومرنة للتعليم تتيح فرص التعلم الجيد المنصف والمناسب مدى الحياة للجميع، وتساهم من خلال ذلك في تحقيق أهداف التنمية المستدامة وبناء المستقبل المشترك للبشر.

٣ - وإذ نذكّر بما ورد في *إعلان تشينغداو* الذي اعتُمد في عام ٢٠١٥ بشأن تسخير تكنولوجيا المعلومات والاتصالات لتحقيق هدف التنمية المستدامة ٤، والذي ينص على وجوب تسخير الوسائل التكنولوجية الحديثة لتعزيز نُظم التعليم وإمكانية انتفاع الجميع بالتعليم، وكذلك التعلم الجيد والفعال والإنصاف والفعالية في تقديم الخدمات، فإننا ندرك ضرورة تلبية الحاجة العاجلة إلى القيام مجدداً بتأكيد وتجديد التزامنا بالعمل من أجل ذلك في ظل انتقالنا إلى عصر يتسم باستخدام الذكاء الاصطناعي على نطاق واسع.

٤ - واستعرضنا الاتجاهات الحديثة في تطور الذكاء الاصطناعي وتأثيره الشديد في المجتمعات البشرية والاقتصادات وسوق العمل، وكذلك في نُظم التعليم والتعلم مدى الحياة. ونظرنا في عواقب الذكاء الاصطناعي على مستقبل العمل وتنمية المهارات، وكذلك في إمكانية استخدام الذكاء الاصطناعي لإعادة تشكيل الأسس الرئيسية للتعليم والتدريس والتعلم.

٥ - ونقرّ بالتعقيد الذي يتسم به الذكاء الاصطناعي وبالتطور السريع في مجال الذكاء الاصطناعي، وبتعدد مفاهيم الذكاء الاصطناعي وكثرة تعريفاته وتنوعها، وبتنوع تطبيقات الذكاء الاصطناعي في سياقات مختلفة، وبالتحديات الأخلاقية الناجمة عن الذكاء الاصطناعي.

٦ - ونقرّ أيضاً بالسمات المميزة للذكاء البشري. ونذكّر بالمبادئ المنصوص عليها في *الإعلان العالمي لحقوق الإنسان*، ونؤكد مجدداً النهج الإنساني لليونسكو في استخدام الذكاء الاصطناعي لحماية حقوق الإنسان وتزويد الناس كافة بالقِيم والمهارات المناسبة اللازمة للتعاون الفعال بين البشر والآلات في الحياة والتعلم والعمل، وكذلك لتحقيق التنمية المستدامة.

٧ - ونؤكد ضرورة التحكم البشري في تطوير الذكاء الاصطناعي وضرورة التركيز في هذا الأمر على الناس، وضرورة تسخير الذكاء الاصطناعي لخدمة الناس وتعزيز القدرات البشرية، وضرورة تصميم وسائل الذكاء الاصطناعي بطريقة أخلاقية منصفة لا يشوبها أي تمييز وتكون شفافة وقابلة للتمحيص، وضرورة رصد وتقييم عواقب الذكاء الاصطناعي على الناس والمجتمع في كل سلاسل القيمة.

ونوصي بأن تقوم الحكومات وسائر الجهات المعنية في الدول الأعضاء في اليونسكو بالنظر، وفقاً لتشريعات الدول الأعضاء وسياساتها العامة وممارساتها، في تنفيذ الإجراءات التالية من أجل اغتنام ما يتعلق بالتعليم من الفرص التي يتيحها الذكاء الاصطناعي والتصدي لما يتعلق بالتعليم من التحديات الناجمة عن الذكاء الاصطناعي:

إدراج التخطيط للذكاء الاصطناعي في السياسات التربوية والتعليمية

٨ - إدراك الطابع المتعدد التخصصات للذكاء الاصطناعي وعواقبه؛ واستخدام الذكاء الاصطناعي في التعليم استخداماً يتوافق مع السياسات العامة، ولا سيّما مع السياسات التربوية والتعليمية؛ واعتماد نهوج شاملة للحكومة برمتها، ونهوج مشتركة بين القطاعات، ونهوج متعددة الجهات المعنية، من أجل التخطيط لاستخدام الذكاء الاصطناعي في التعليم وإدارة أمور استخدامه في التعليم؛ وتحديد الأولويات الاستراتيجية استناداً إلى المصاعب المحلية التي تعترض المساعي الرامية إلى تحقيق هدف التنمية المستدامة ٤ وغاياته، وكذلك المساعي الرامية إلى تحقيق سائر أهداف التنمية المستدامة؛ والتخطيط لوضع استراتيجيات متسقة وشاملة للمنظومة التعليمية برمتها لاستخدام الذكاء الاصطناعي في التعليم، ووضع تلك الاستراتيجيات وضمان توافقها مع السياسات التربوية والتعليمية ودمجها فيها سعياً إلى إتاحة التعلم مدى الحياة.

٩ - وإدراك متطلبات الاستثمار في تنفيذ سياسات وبرامج استخدام الذكاء الاصطناعي في التعليم. والنظر في أوجه التوازن بين مختلف أولويات السياسات التربوية والتعليمية وتحديد مصادر مختلفة للتمويل، ومنها مصادر تمويل وطنية (عامة وخاصة)، واستخدام آليات التمويل الدولية وآليات التمويل المبتكرة. والنظر أيضاً في إمكانية استخدام الذكاء الاصطناعي للجمع بين مصادر متعددة للبيانات وتحليل البيانات المتوفرة فيها من أجل تحسين فعالية اتخاذ القرارات.

استخدام الذكاء الاصطناعي لإدارة شؤون التعليم وتوفير التعليم

١٠- إدراك التقدم المحرز في استخدام البيانات لتغيير إجراءات التخطيط لوضع السياسات القائمة على البيّنات. والنظر في ابتكار أو استخدام أدوات ووسائل تكنولوجيا الذكاء الاصطناعي المناسبة لتحسين نُظم المعلومات الخاصة بإدارة شؤون التعليم من أجل تعزيز جمع البيانات ومعالجتها سعياً إلى إدارة شؤون التعليم وتوفير التعليم بطريقة أكثر إنصافاً وشمولاً وانفتاحاً وملاءمة للاحتياجات الفردية.

١١- والنظر أيضاً في الأخذ بما يمكن أن يتيحه استخدام الذكاء الاصطناعي من نماذج جديدة لتوفير التعليم والتدريب في مختلف مؤسسات وأماكن التعلم من أجل خدمة مختلف الأطراف الفاعلة التي تضم مثلاً الطلاب والمدرّسين وأولياء الأمور والمجتمعات المحلية.

استخدام الذكاء الاصطناعي لتعزيز التدريس وتمكين المعلمين

١٢- إدراك ضرورة بقاء التفاعل بين البشر والتعاون بين المعلمين والمتعلمين في صميم العملية التعليمية، علماً بأن الذكاء الاصطناعي يتيح فرصاً لمساعدة المعلمين على الاضطلاع بمسؤولياتهم التربوية والتعليمية. وإدراك أنه لا يمكن للآلات أن تحلّ محلّ المعلمين، وضمان حماية حقوق المعلمين وظروف عملهم.

١٣- واستعراض أدوار المعلمين والكفاءات اللازمة لديهم وتحديدها بطريقة فعالة في إطار السياسات الخاصة بالمعلمين، وتعزيز مؤسسات إعداد وتدريب المعلمين، ووضع برامج ملائمة لبناء القدرات من أجل إعداد المعلمين للعمل بفعالية في أجواء تعليمية زاخرة بالذكاء الاصطناعي.

استخدام الذكاء الاصطناعي لإتاحة التعلم وتقييم نتائجه

١٤- الوقوف على الاتجاهات المتعلقة بإمكانية استخدام الذكاء الاصطناعي للمساعدة على إتاحة التعلم وتقييم نتائجه، ومراجعة المناهج الدراسية وتعديلها لتعزيز إدماج الذكاء الاصطناعي إدماجاً مستفيضاً فيها وتغيير منهجيات التعلم. والنظر في استخدام أدوات متوفرة للذكاء الاصطناعي، أو في وضع حلول مبتكرة قائمة على الذكاء الاصطناعي، يبدو جلياً فيها أن فوائد استخدام الذكاء الاصطناعي تفوق المخاطر، من أجل تيسير تحديد المهام الخاصة بالتعلم تحديداً جيداً في مختلف المواد الدراسية ودعم ابتكار وتطوير أدوات الذكاء الاصطناعي اللازمة لاكتساب المهارات والكفاءات الجامعة للتخصصات.

١٥- ودعم إجراء اختبارات تجريبية على نطاق المدرسة لاستخدام الذكاء الاصطناعي لتيسير الابتكار في التدريس والتعلم، واستخلاص العِبر من التجارب الناجحة وتعزيز الممارسات القائمة على البيّنات.

١٦- واستخدام أو ابتكار أدوات للذكاء الاصطناعي لدعم عمليات التعلم القابلة للتكيف؛ والاستفادة من إمكانية استخدام البيانات لإتاحة تقييم الأبعاد المتعددة لكفاءات الطلاب؛ والمساعدة على الاضطلاع بتقييم واسع النطاق عن بُعد.

تعزيز القِيم وتنمية المهارات اللازمة للحياة والعمل في عصر الذكاء الاصطناعي

١٧- إدراك التغير المنهجي الطويل الأجل الذي يطرأ على سوق العمل، والذي يشمل العوامل الجنسانية لسوق العمل، من جرّاء استخدام الذكاء الاصطناعي. وتحديث وتطوير الآليات والأدوات المستخدمة لتحديد الاحتياجات الحالية والتنبؤ بالاحتياجات المستقبلية فيما يخص المهارات المتعلقة بتطوير الذكاء الاصطناعي سعياً إلى ضمان ملاءمة المناهج الدراسية للاقتصادات وأسواق العمل والمجتمعات المتغيرة. وإدراج المهارات المتعلقة بالذكاء الاصطناعي في المناهج الدراسية والمؤهلات الخاصة بالتعليم والتدريب في المجال التقني والمهني وبالتعليم العالي، مع مراعاة الجوانب الأخلاقية والتخصصات الإنسانية المترابطة.

١٨- وإدراك ظهور مجموعة من مهارات الدراية بالذكاء الاصطناعي اللازمة للتعاون الفعال بين البشر والآلات بدون إغفال الحاجة إلى المهارات الأساسية التي تضم مثلاً مهارات القراءة والكتابة والحساب. واتخاذ إجراءات مؤسسية لتعزيز الدراية بالذكاء الاصطناعي لدى جميع شرائح المجتمع.

١٩- ووضع خطط متوسطة أو طويلة الأجل واتخاذ إجراءات عاجلة لمساعدة مؤسسات التعليم العالي والمؤسسات البحثية على إعداد أو تعزيز البرامج الدراسية والبحثية الرامية إلى تنمية المواهب المحلية المتعلقة بالذكاء الاصطناعي من أجل إيجاد مجموعة كبيرة من المهنيين المحليين الذين يعملون في مجال الذكاء الاصطناعي ويملكون الخبرة اللازمة لتصميم نُظم الذكاء الاصطناعي وبرمجتها وتطويرها.

استخدام الذكاء الاصطناعي لإتاحة فرص التعلم مدى الحياة للجميع

٢٠- تجديد تأكيد اعتبار التعلم مدى الحياة المبدأ التوجيهي للمساعي الرامية إلى تحقيق هدف التنمية المستدامة ٤، ويشمل هذا الأمر التعلم النظامي وغير النظامي وغير الرسمي. واستخدام برامج الذكاء الاصطناعي وأدوات تحليل البيانات الخاصة بالتعلم كوسائل تكنولوجية رئيسية لوضع نُظم متكاملة للتعلم مدى الحياة من أجل إتاحة التعلم الملائم لاحتياجات المتعلم ووسائله في أي زمان ومكان، وربما لأي شخص كان. وتسخير إمكانيات الذكاء الاصطناعي لإتاحة سُبل مرنة للتعلم وإتاحة تجميع نتائج التعلم المتفرقة والاعتراف بها والتصديق عليها ونقلها.

٢١- وإدراك ضرورة إبداء الاهتمام اللازم باحتياجات الأشخاص المسنّين، ولا سيّما النساء المسنّات، عند وضع السياسات، وكذلك ضرورة إشراك المسنّين والمسنّات في تعزيز القِيم وتنمية المهارات اللازمة للعيش في عصر الذكاء الاصطناعي من أجل إزالة العوائق التي تحول دون التمتع بالحياة الرقمية. والتخطيط لبرامج ممولة تمويلاً جيداً وتنفيذها لتزويد العاملين المسنّين بالمهارات والخيارات اللازمة لتمكينهم من مواصلة نشاطهم الاقتصادي ما داموا يريدون ذلك وتمكينهم من المشاركة في حياة مجتمعاتهم.

تعزيز استخدام الذكاء الاصطناعي في التعليم استخداماً منصفاً وشاملاً للجميع

٢٢- تجديد تأكيد اعتبار ضمان الشمول والإنصاف في التعليم ومن خلال التعليم، وإتاحة فرص التعلم مدى الحياة للجميع، الركنين الأساسيين لتحقيق هدف التنمية المستدامة ٤ الخاص بالتعليم حتى عام ٢٠٣٠. وتجديد تأكيد اعتبار التقدم التكنولوجي المحرز في مجال استخدام الذكاء الاصطناعي في التعليم فرصة لتحسين سُبل الانتفاع بالتعليم المتاحة لأشد الفئات ضعفاً.

٢٣- وضمان استخدام الذكاء الاصطناعي استخداماً يؤدي إلى تعزيز جودة فرص التعليم والتعلم وإتاحتها للجميع بغض النظر عن الجنس أو الإعاقة أو الوضع الاجتماعي أو الاقتصادي أو الأصل الإثني أو الخلفية الثقافية أو الموقع الجغرافي. فلا ينبغي أن يؤدي تطوير واستخدام الذكاء الاصطناعي في التعليم إلى اتساع الفجوة الرقمية، ويجب ألا ينطوي تطويره واستخدامه على أي تحيّز يضرّ بأية أقلية أو فئة ضعيفة.

٢٤- وضمان استخدام الذكاء الاصطناعي في التدريس والتعلم استخداماً يتيح الإدماج الفعلي للطلاب الذين يعانون من مصاعب في التعلم أو من إعاقات والطلاب الذين يدرسون بلغة أخرى غير لغتهم الأم.

المساواة بين الجنسين فيما يخص الذكاء الاصطناعي واستخدام الذكاء الاصطناعي لتحقيق المساواة بين الجنسين

٢٥- التشديد على أن الفجوة بين الجنسين في المهارات الرقمية تساهم في انخفاض عدد النساء بين المهنيين العاملين في مجال الذكاء الاصطناعي وتؤدي إلى تفاقم أوجه عدم المساواة الموجودة بين الجنسين.

٢٦- وتأكيد الالتزام بابتكار تطبيقات لاستخدام الذكاء الاصطناعي في التعليم تخلو من التحيز الجنساني، وكذلك الالتزام بضمان مراعاة المساواة بين الجنسين في البيانات المستخدمة لأغراض تطوير الذكاء الاصطناعي. وينبغي لتطبيقات الذكاء الاصطناعي أن تعزز المساواة بين الجنسين.

٢٧- وتعزيز المساواة بين الجنسين في مجال ابتكار وتطوير أدوات الذكاء الاصطناعي، وتمكين الفتيات والنساء من اكتساب مهارات الذكاء الاصطناعي لتعزيز المساواة بين الجنسين لدى العاملين وأرباب العمل في مجال الذكاء الاصطناعي.

ضمان استخدام البيانات والخوارزميات الخاصة بالتعليم بطريقة أخلاقية وشفافة وقابلة للتمحيص

٢٨- إدراك إمكانية تسبب تطبيقات الذكاء الاصطناعي في إيجاد أنواع وأشكال مختلفة للتحيز تنطوي عليها البيانات التي يجري تدريب وسائل تكنولوجيا الذكاء الاصطناعي عليها والتي يجري استخدامها كمُدخلات في تلك الوسائل، كما تنطوي عليها طريقة إعداد واستخدام العمليات والخوارزميات. وإدراك معضلات إيجاد توازن بين الانتفاع الحر بالبيانات وحماية خصوصية البيانات. وإدراك المسائل القانونية والمخاطر الأخلاقية المرتبطة بملكية البيانات وخصوصية البيانات وتوفير البيانات من أجل الصالح العام. وإدراك أهمية اعتماد مبادئ مراعاة الأخلاقيات والخصوصية والأمن طوال عملية التصميم.

٢٩- واختبار أدوات ووسائل تكنولوجيا الذكاء الاصطناعي الحديثة واستخدامها لضمان حماية خصوصية بيانات المعلمين والمتعلمين وضمان أمن البيانات. ودعم الدراسة الـمُحكمة والطويلة الأجل لمسائل الأخلاقيات الأكثر صعوبة في مجال الذكاء الاصطناعي، وضمان استخدام الذكاء الاصطناعي لأغراض جيدة والحيلولة دون استخدام تطبيقاته الضارة. ووضع قوانين وأُطر تنظيمية شاملة لحماية البيانات من أجل ضمان استخدام وإعادة استخدام بيانات المتعلمين بطريقة أخلاقية منصفة لا يشوبها أي تمييز وتكون شفافة وقابلة للتمحيص.

٣٠- وتعديل الأُطر التنظيمية الموجودة أو اعتماد أُطر تنظيمية جديدة لضمان ابتكار وتطوير أدوات الذكاء الاصطناعي واستخدامها بطريقة مسؤولة لأغراض التعليم والتعلم. وتيسير إجراء مناقشات البحث بشأن المسائل المرتبطة بأخلاقيات الذكاء الاصطناعي وخصوصية وأمن البيانات، وكذلك بشأن الشواغل المتعلقة بعواقب الذكاء الاصطناعي السلبية على حقوق الإنسان والمساواة بين الجنسين.

الرصد والتقييم والبحث

٣١- إدراك الافتقار إلى دراسات منهجية بشأن عواقب تطبيقات الذكاء الاصطناعي على التعليم. ودعم مساعي البحث والابتكار والتحليل المتعلقة بعواقب الذكاء الاصطناعي على الممارسات الخاصة بالتعلم وعلى نتائج التعلم، وكذلك على ظهور واعتماد أشكال جديدة للتعلم. والأخذ بنهج جامع للتخصصات لإجراء بحوث بشأن استخدام الذكاء الاصطناعي في التعليم. والتشجيع على الاضطلاع بأنشطة عابرة للحدود الوطنية لأغراض البحث المقارن والتعاون.

٣٢- والنظر في وضع آليات للرصد والتقييم لقياس مدى تأثير الذكاء الاصطناعي في التعليم والتدريس والتعلم من أجل إرساء أساس سليم ومتين وقائم على البيّنات لاتخاذ القرارات.

ونوصي بأن تقوم المنظمات الدولية والجهات الشريكة الفاعلة في مجال الذكاء الاصطناعي بالنظر في تنفيذ الإجراءات التالية:

التمويل والشراكة والتعاون الدولي

٣٣- رصد وتقييم عواقب الفجوة الموجودة بين البلدان في مجال الذكاء الاصطناعي، وكذلك عواقب الفوارق الموجودة بينها في مجال تطوير الذكاء الاصطناعي، استناداً إلى بيانات تقدمها البلدان طوعاً. وإدراك مخاطر الاستقطاب والانقسام بين المنتفعين بالذكاء الاصطناعي وغير المنتفعين به. وتجديد التشديد على أهمية معالجة هذه الشواغل، مع إيلاء أولوية خاصة لأفريقيا وأقل البلدان نمواً والدول الجزرية الصغيرة النامية والبلدان المتضررة من النزاعات والكوارث.

٣٤- وتنسيق المساعي الجماعية الرامية إلى تعزيز الاستخدام المنصف للذكاء الاصطناعي في التعليم ضمن الأُطر العالمية والإقليمية الخاصة بالتعليم حتى عام ٢٠٣٠، وذلك بوسائل تضم تشاطر تكنولوجيا الذكاء الاصطناعي والبرامج والموارد المتعلقة بالذكاء الاصطناعي من أجل بناء القدرات، مع مراعاة وجوب احترام حقوق الإنسان والمساواة بين الجنسين.

٣٥- ودعم عمليات الاستعراض الاستشرافية لأحدث المسائل المتعلقة بعواقب ابتكار وتطوير وسائل تكنولوجيا الذكاء الاصطناعي الحديثة، وتيسير استطلاع استراتيجيات وممارسات فعالة لاستخدام الذكاء الاصطناعي لأغراض الابتكار في التعليم من أجل إيجاد أوساط دولية ذات آراء مشتركة بشأن الذكاء الاصطناعي والتعليم.

٣٦- ومواءمة التعاون الدولي مع الاحتياجات الوطنية الخاصة بتطوير واستخدام الذكاء الاصطناعي في التعليم، وكذلك بالتعاون بين القطاعات، من أجل تعزيز إمساك العاملين في مجال الذكاء الاصطناعي بزمام الأمور فيما يخص ابتكار وتطوير وسائل تكنولوجيا الذكاء الاصطناعي. وتعزيز تبادل المعلومات وتشاطر الممارسات الواعدة، وتعزيز إجراءات التنسيق والتكامل بين البلدان.

٣٧- وإيجاد محافل ملائمة للتبادل الدولي للمعلومات المتعلقة بالأُطر والوثائق والنهوج الخاصة بتنظيم استخدام الذكاء الاصطناعي في التعليم بوسائل تضم أسبوع اليونسكو للتعلم بالأجهزة المحمولة والاستعانة بوكالات أخرى للأمم المتحدة، والعمل بذلك على دعم التعاون فيما بين بلدان الجنوب والتعاون بين بلدان الشمال وبلدان الجنوب بشأن تسخير الذكاء الاصطناعي لتحقيق هدف التنمية المستدامة ٤ وعلى الاستفادة من هذا التعاون.

٣٨- وإقامة شراكات متعددة الجهات المعنية وتعبئة موارد للحدّ من الفجوة الموجودة فيما يخص الذكاء الاصطناعي وزيادة الاستثمار في استخدام الذكاء الاصطناعي في التعليم.

وندعو المدير العام لليونسكو إلى السعي إلى تنفيذ الإجراءات التالية:

٣٩- إنشاء منتدى لاستخدام الذكاء الاصطناعي من أجل التعليم سعياً إلى إتاحة تبادل المعلومات المتعلقة بالبرامج الدراسية المفتوحة المصدر الخاصة بالذكاء الاصطناعي والمعلومات المتعلقة بأدوات الذكاء الاصطناعي، وكذلك معلومات عن أمثلة على سياسات استخدام الذكاء الاصطناعي في التعليم، وعن الأُطر التنظيمية وأفضل الممارسات في مجال استخدام الذكاء الاصطناعي في التعليم، من أجل تعزيز استخدام الذكاء الاصطناعي لتحقيق هدف التنمية المستدامة ٤، والمساعدة على بحث مستقبل التربية والتعليم والتعلم، وإتاحة الانتفاع بالموارد والبرامج الدراسية المفتوحة المصدر الخاصة بالذكاء الاصطناعي للجميع.

٤٠- ووضع مبادئ توجيهية وإعداد موارد بالتشاور مع الدول الأعضاء من أجل المساعدة على وضع السياسات والاستراتيجيات اللازمة لاستخدام الذكاء الاصطناعي في التعليم استخداماً فعالاً ومنصفاً. والمساعدة على بناء قدرات واضعي السياسات التربوية والتعليمية.

٤١- وتعزيز دور اليونسكو الريادي في مجال استخدام الذكاء الاصطناعي في التعليم داخل جميع القطاعات أو الأقسام أو الإدارات المعنية، وتعبئة معاهد المنظمة وشبكاتها لهذا الغرض.

٤٢- والمساعدة على إدراج مهارات الذكاء الاصطناعي في أُطر مؤهلات المعلمين الخاصة بتكنولوجيا المعلومات والاتصالات، ومساعدة البلدان على تدريب المدرّسين على العمل في أجواء تعليمية زاخرة بالذكاء الاصطناعي.

٤٣- ومواصلة العمل على توسيع نطاق تعاون اليونسكو، في مجال استخدام الذكاء الاصطناعي في التعليم، مع الشركاء المعنيين من كيانات الأمم المتحدة والكيانات الأخرى المتعددة الأطراف، وكذلك مع مصارف التنمية الإقليمية والمنظمات الإقليمية والقطاع الخاص.

٤٤- واتخاذ تدابير المتابعة الملائمة بشأن المؤتمر على الصعيدين الإقليمي والدولي، والعمل في هذا الصدد بالتعاون مع الشركاء في التنمية الناشطين في هذا المجال، من أجل الاستناد إلى التوافق الذي تمخض عنه المؤتمر وتوسيع نطاق تأثير هذا التوافق.

United Nations
Educational, Scientific and
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науки и культуры

منظمة الأمم المتحدة
للتربية والعلم والثقافة

联合国教育、
科学及文化组织

توافق بيجين

انتهاز فرص الانتفاع بالتكنولوجيات الرقمية وريادة التحول في مجال التعليم

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on artificial intelligence and education

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人工智能与教育

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人工智能与教育

政策制定者指南



2030年
教育

UNESCO——全球教育领导机构

教育是联合国教科文组织工作的重中之重，它既是一项基本人权，也是建设和平和推动可持续发展的基础。教科文组织是主管教育的联合国专门机构，在全球和地区的教育领域发挥领导作用，以推动各国教育系统的发展，增强其韧性和能力，从而服务所有学习者。教科文组织通过变革性学习引领应对当今全球挑战的行动，并在所有业务领域重视性别平等和非洲。

2030年全球教育议程

教科文组织作为主管教育的联合国专门机构，负责领导并协调2030年教育议程——旨在通过17项可持续发展目标在2030年前消除贫穷的全球运动的一部分。教育既是实现各项可持续发展目标的关键，同时自身也是单独一项目标（可持续发展目标4），即“**确保包容和公平的优质教育，让全民终身享有学习机会**”。《2030年教育行动框架》为落实这一宏伟目标及各项承诺提供了指导方针。

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联合国教育、
科学及文化组织

2030年
教育

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概　述

人工智能与教育：前景与启示

人工智能（Artificial Intelligence，AI）有望解决当今教育面临的部分重大挑战，革新教学实践，最终加快迈向可持续发展目标4的进程。然而，这些技术的快速发展不可避免地带来了种种风险和挑战，目前相应政策讨论与监管框架变革的速度已赶不上其发展速度。

本出版物为政策制定者提供指南，指导政策制定者充分利用人工智能与教育深度融合带来的机遇以及应对随之而来的风险。



本出版物开篇讲述人工智能的相关必备知识：定义、底层技术和技术应用。然后，详细分析人工智能新兴趋势及其对教学的影响，包括我们如何确保人工智能技术在教育中的应用合乎伦理、包容和公平，教育如何能够帮助人类与人工智能共处与合作，以及如何发掘人工智能潜力促进教育发展。最后，本出版物论述了利用人工智能实现可持续发展目标4所面临的挑战，并且为政策制定者因地制宜规划政策和项目提供切实可行的建议。

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“战争起源于人之思想，
故务需于人之思想中
筑起保卫和平之屏障。”

序

人工智能（Artificial Intelligence，AI）技术的迅速发展对教育产生着重大影响。人工智能赋能解决方案的进步蕴含着巨大潜力，有望促进社会公益事业和实现可持续发展目标。要使这些成为现实，离不开全系统的政策调整以及对健全的伦理监督的呼吁，也离不开全球从业人员和研究人员的深度参与。

政策制定者和教育工作者已然走进未知领域，面临有关未来学习如何与人工智能相互作用的基本问题。人工智能技术在教育中的部署和应用必须遵循包容和公平的原则，这是底线。为此，相关政策必须促进公平和普惠地获取人工智能技术，倡导将人工智能技术作为一种共有物品（public good）的非排他性应用，并注重赋能女童、妇女和社会经济弱势群体。新型人工智能技术在教育中的应用日益增长。如若人工智能技术在设计上有意增进以人为本的教学法并尊重伦理规范及标准，那么这一趋势对整个人类有益无害。人工智能技术应以促进每个学生学习、赋能教师队伍和强化学习管理系统为导向。除此之外，帮助受教育者和全体公民在生活和工作中安全有效地利用人工智能是全球范围内面临的一大共同挑战。未来的学习和培训系统必须让所有人具备核心人工智能素养，包括了解人工智能技术如何收集和操纵数据，以及确保个人数据安全和保护的技能。最终，人工智能在本质上是跨行业部门的。有效的人工智能与教育政策规划离不开与各学科领域及部门的利益相关方进行磋商协作。

在促进与关键公私部门参与者就这些领域开展对话、掌握相关知识方面，教科文组织一直发挥着牵头作用。各种活动和出版物已使各方进一步认识到人工智能给教育带来的大量机遇和深刻影响，帮助教科文组织成员国着手应对各种复杂挑战。2019年，联合国的教育领域信息通信技术旗舰项目“移动学习周”探讨了人工智能与可持续发展之间的关系。

同年，教科文组织与中国政府在北京携手主办“国际人工智能与教育大会”，主题是“规划人工智能时代的教育：引领与跨越”。大会探讨了人工智能对教育的全系统影响，同时通过并发布成果文件《北京共识》。这是有史以来第一份就如何充分利用人工智能技术实现“可持续发展目标4——2030年教育”提出建议的文件。《北京共识》明确建议，教科文组织应该提供相关指引和资源，以支持教育政策制定者的能力建设，并将人工智能技能纳入信息通信技术能力框架。更广泛地讲，该文件呼吁教科文组织纵观全局，与相关伙伴一起加强在人工智能与教育领域的国际合作。



《人工智能与教育：政策制定者指南》是在《北京共识》实施框架下编制的，旨在培养教育领域具备人工智能素养的政策制定者。本出版物会充实教科文组织日益扩展的教育领域智力成果库，并旨在服务政策制定和教育领域的实践人员与专业人士。本出版物旨在形成对于人工智能给教育带来的机遇的共同认知，及其对人工智能时代必备素养的启示的理解。本出版物通过呈现一份效益风险评估，以此来激发各方发挥批判性思维思考如何借助人工智能技术应对实现可持续发展目标4过程中面临的挑战，以及如何发现和化解潜在风险。本出版物汇集了相关的新兴国家政策，以及如何借助人工智能强化教学质量的实践典范。本出版物也可作为制定人工智能与教育政策的指导手册，从规划人本的和战略性目标，到制定关键建设政策组成部分和实施策略，皆有助益。

因此，我希望本出版物中提出的关键政策问题、分析的经验教训以及分享以人为本的政策方针能够帮助各国政府和合作伙伴有效部署人工智能技术，促进教育和培训体系转型，使之服务于社会共同利益，打造一个包容的、可持续的未来。



Stefania Giannini
联合国教科文组织
教育助理总干事

致谢

本出版物是人工智能与教育界专家共同努力的成果。

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人工智能与教育:
政策制定者指南

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缩略语表

AI	Artificial Intelligence	人工智能
AI TA	AI Teaching Assistant	人工智能助教
ANN	Artificial Neural Network	人工神经网络
AR	Augmented Reality	增强现实
AWE	Automated Writing Evaluation	作文自动评阅
CNN	Convolutional Neural Network	卷积神经网络
DBTS	Dialogue-Based Tutoring System	基于对话的导学系统
DigComp	European Digital Competence Framework	欧洲公民数字能力框架
DNN	Deep Neural Networks	深度神经网络
EEG	Electroencephalography	脑电图
ELE	Exploratory Learning Environment	探索性学习环境
EMIS	Education Management Information System	教育管理信息系统
GAN	Generative Adversarial Network	生成式对抗网络
GDPR	General Data Protection Regulation	《通用数据保护条例》
GOFAI	Good-Old-Fashioned AI	有效的老式人工智能
ICT	Information and Communication Technology	信息通信技术
ILO	International Labour Organization	国际劳工组织
ITS	Intelligent Tutoring Systems	智能导学系统
IoT	Internet of Things	物联网
LMS	Learning Management System	学习管理系统
LNO	Learning Network Orchestrator	学习网络协调器
LSTM	Long Short-Term Memory	长时短期记忆
ML	Machine Learning	机器学习
NLP	Natural Language Processing	自然语言处理
OER	Open Educational Resources	开放教育资源
RNN	Recurrent Neural Network	循环神经网络
SDG	Sustainable Development Goal	可持续发展目标
STEM	Science, Technology, Engineering, and Mathematics	科学、技术、工程和数学
TVET	Technical and Vocational Education and Training	职业技术教育与培训
UNESCO	United Nations Educational, Scientific, and Cultural Organization	联合国教育、科学及文化组织
VR	Virtual Reality	虚拟现实

1. 引言

在过去短短五年间，由于某些突出成就和颠覆性潜力，人工智能已走出学术研究的象牙塔，成为公众讨论的前沿焦点，自然也受到了联合国专家的关注。在许多国家，人工智能在日常生活之中已经普及——从智能手机的个人助理到客服聊天机器人，从娱乐信息推荐到犯罪行为预测，从人脸识别到医疗诊断，人工智能应用无处不在。

然而，尽管人工智能有可能帮助各方实现联合国可持续发展目标（SDGs），但是日新月异的技术不可避免地带来了种种风险和挑战，目前相应的政策讨论与监管框架的变革速度已远远落后于其发展速度。而且，尽管人们对其主要的顾虑还停留在人工智能是否会强大到碾压人类主体，但是涉及人工智能的社会和伦理影响则引发人们更加迫在眉睫的担忧——例如，滥用个人数据以及人工智能其实可能无法缓解，反而加剧现有的不平等现象。

尽管如此，人工智能已经进入教育领域。“智能”、“自适应”和“个性化”学习系统日益增多。私营企业纷纷开发这些系统，以供全球广大中小学和高校使用。人工智能教育应用市场应运而生，预计2024年将达到60亿美元的市场规模（Bhutani和Wadhwani，2018）。人工智能技术在教育领域的应用不可避免地带来了深层次问题——比如，教学内容与方式、教师的角色演变以及人工智能的社会和伦理影响。同时，其应用带来了许多挑战，包括教育公平和机会均等。各方也逐渐达成一个共识：人工智能技术在教育领域的部署应用或将重塑教学的根基。

新冠肺炎疫情期间，学校封闭带来的在线教学巨大转变使得上述问题变得更加复杂。

因此，联合国教科文组织的这一指导意见力求帮助政策制定者更好地了解人工智能给教学带来的可能性与影响，以期人工智能在教育领域的应用能够真正有助于实现可持续发展目标4：“确保包容和公平的优质教育，让全民终身享有学习机会”。

我们也必须认识到，人工智能与教育之间的联系难免会产生参差不齐的结果，具体因各国社会经济环境而异。

通常情况下，我们对人工智能技术的担忧在于，

> **如果我们继续盲目前进，那么可以预料，未来不平等现象、经济崩坏和社会动荡皆会加剧，甚至在某些情况下政局不稳也会加剧，其中在技术上处于劣势和被忽视的群体处境最糟。（Smith和Neupane，2018，第12页）**

在人工智能与教育领域，这种担忧只多不少。如果想将人工智能用于帮助实现可持续发展目标4，还需要提供廉价的人工智能技术开发模式，确保低收入和中等收入国家的利益也被纳入关键讨论与决策之中，并且在这些国家与人工智能技术相对先进的国家之间搭建桥梁。本出版物首先简要介绍了人工智能的定义及运作机制，为深入论述人工智能与教育之间的相互作用奠定基础。随后，本出版物介绍了当前人工智能在教育领域的多种应用，以及人工智能如何促进教育包容性和公平性、提高学习质量以及完善教育管理和教学法。这部分内容还探讨了教育如何帮助公民发展人工智能时代生活和工作所需的技能。接下来，本出版物详细介绍了主要战略目标——利用人工智能给教育带来的益处、化解相关风险，同时探讨了实现这些目标面临的挑战。最后，本出版物提出一系列建议作为结语，旨在为人工智能与教育政策的全面愿景和行动方案提供参考。

2. 政策制定者关于人工智能的必备知识

2.1 人工智能的跨学科本质

“人工智能（artificial intelligence）”一词最早出现在1956年美国常春藤盟校达特茅斯学院举办的一场研讨会上，用来描述“用于打造智能机器、尤其是智能计算机程序的科学和工程技术”（McCarthy等人，2006，第2页）[1]。此后数十年里，人工智能的发展断断续续，时而飞速进步，时而经历寒冬（Russell和Norvig，2016）。

一直以来，人工智能的各种定义不断增多、延伸，而且往往牵涉到哲学问题，比如：什么构成“智能”？机器是否真的能够获得“智力”？在此仅举一例，钟义信对人工智能的定义如下：

> **现代科技的一门分支学科，旨在探索人类智能奥秘，同时最大限度将人类智能移植到机器上，使机器能够像人类一样智能地执行功能。（Zhong，2006，第90页）**

如若务实地绕开这个长期争论，在本出版物中，可将人工智能定义为是一种被设计出来以人类能力与世界进行互动的计算机系统（Luckin等人，2016）。而教科文组织世界科学知识与技术伦理委员会（COMEST）给出更多细节，将人工智能描述为涉及

> **能够模仿人类智能某些功能的机器，具体功能包括感知、学习、推理、解决问题、语言互动、甚至创造性工作等。（COMEST，2019）**

目前，我们正在经历一场人工智能复兴，越来越多的行业部门开始应用机器学习技术。这种人工智能技术涉及人工智能系统分析海量数据。这是两大关键发展趋势共同作用的结果：一是数据呈指数级增长（据IBM计算，由于互联网和相关技术普及，每天创建的数据量超过250亿亿个字节[2]），二是计算机处理能力呈指数级增长（由于摩尔定律，如今的手机与40年前的超级计算机一样强大）。大数据和强大的计算机均是机器学习技术取得成功的必要条件，因为这种技术的算法依赖于对数百万个数据点的处理，而后者又离不开庞大的计算机处理能力。[3]

有意思的是，最常登上新闻头条的机器学习算法（“深度学习”和“神经网络”）本身已经存在40多年了。

表1：“人工智能即服务（AI-AS-A-SERVICE）”示例

科技公司	“人工智能即服务”平台	公司官方描述
阿里巴巴	阿里云 (Alibaba Cloud)	提供各种基于云的人工智能工具，满足企业、网站或应用的需求：https://www.alibabacloud.com
亚马逊	AWS	提供计算机视觉、语言、推荐和预测所需的预训练人工智能服务。能够大规模快速构建、训练和部署机器学习模型，或者构建为全部流行开源框架支持的定制模型：https://aws.amazon.com/machine-learning
百度	飞桨 (EasyDL)	支持客户构建无需编写代码的优质定制人工智能模型：https://ai.baidu.com/easydl
谷歌	TensorFlow	端到端的机器学习开源平台，提供涵盖工具、资料库和社群资源的生态系统，使研究人员能够共享最先进的机器学习技术，使开发者能够轻易构建和部署机器学习赋能的应用程序：https://www.tensorflow.org
IBM	Watson	让用户能够对任何主机平台上的数据使用人工智能工具和应用程序：https://www.ibm.com/watson
微软	Azure	提供100多项构建、部署和管理应用程序的服务：https://azure.microsoft.com
腾讯	众创空间 (WeStart)	汇集各种人工智能能力、专业人才和行业资源，支持初创企业开设或改进。连通行业伙伴，传播人工智能技术，使之广泛应用于多个行业部门：https://westart.tencent.com/ai

如今，世界上几乎所有的科技巨头以及许多其他科技公司都提供精深的“人工智能即服务”平台，其中部分是开源平台。这些平台提供了各种人工智能基础模块可供开发者使用，而无需从零开始编写人工智能算法。

既然如此，为什么人工智能技术的瞩目成就及其颠覆性潜力近些年来才显露出来？这是因为对人工智能算法巧妙地改进，同时人们也更加容易获得“人工智能即服务”，而不是出于任何根本性的新范式。换言之，可以说目前我们身处“实施期（大规模实际应用时期）”：

人工智能研究的很多艰深且抽象的工作已经完成……“实施期（大规模实际应用时期）”意味着，我们将最终看到这些成果在现实世界中的应用。（Lee，2018，第13页）

如今，人工智能技术在现实世界的应用越来越普遍且具有颠覆性。众所周知的例子包括自动语言翻译、自动人脸识别（用于识别旅客和追踪罪犯），以及我们日常生活中的应用，比如无人驾驶汽车、智能手机和其他设备上的个人助理程序等。医疗行业是一个特别值得关注的领域。最近一个具有变革性的例子就是应用人工智能技术研发能够杀死多种抗药性细菌的新药（Trafton，2020）。第二个例子是应用人工智能技术来分析医学影像——包括可以及早显示异常畸形的胎儿脑部扫描[4]、帮助诊断糖尿病的视网膜扫描[5]以及可以提高肿瘤检测水平的X光[6]。这些例子均说明了人工智能与人共生协作带来的重大潜在效益。

当我们把基于人工智能的成像技术与放射科医生结合起来后，我们发现，二者结合的表现优于人工智能或放射科医生单独的表现。（Michael Brady，牛津大学肿瘤学教授，引自《麻省理工技术评论和GE医疗》上发表的文章，2019）

最近的这篇评论进一步表明，人工智能技术其实可以使医疗“更人性化”：

随着人工智能和自动化流程发展，往往各种担忧随之而来，比如医疗服务提供过程中会丧失人情味。然而，业界发现，事实正好相反：人工智能可以为超负荷工作的医疗专业人士拓展资源和能力，极大地完善医疗服务流程。（《麻省理工技术评论和GE医疗》，2019）

其他日益常见的人工智能应用领域包括：

- **自动新闻**
人工智能代理程序不断监测全球新闻媒体，为记者提取关键资讯，同时也自动撰写一些简单的新闻报道；

- **人工智能法律服务**
例如，提供自动取证工具，研究判例法和成文法，以及开展法律尽职调查；

- **人工智能天气预报**
挖掘和自动分析大量历史气象数据，在此基础上预测天气；

- **人工智能诈骗侦测**
自动监测信用卡使用情况，从中发现规律和异常情况（即潜在欺诈性交易）；

- **人工智能驱动的商业流程**
例如，自主生产制造、市场分析、股票交易和投资组合管理；

- **智慧城市**
采用人工智能技术和互联的物联网（IoT）来提高城市中人们的生活与工作效率和可持续性；

- **人工智能机器人**
采用机器视觉、强化学习等人工智能技术作为辅助与世界进行互动的物理机器。

上述例子对社会具有显著的积极影响力，不过，我们不应忽的是人工智能在其他领域的应用会比较有争议。以下为两个例子：

- **自主作战**
无需人为干预即可运作的武器、无人机和其他军事装备；

- **深伪（deep-fakes）**
自动生成假新闻，替换视频中的人物面孔，让人误以为政客和名人说了或做了什么，但其实当事人从未说过或做过。

此外，在评估一些人工智能技术公司和媒体的许多夸大言论时，我们也应当谨慎。首先，尽管新闻头条宣称，如今的人工智能工具在执行某些任务时表现“优于”人类，比如阅读文本和识别图像中的物体等，但现实是，这些成功只在有限的情形下是成立的——例如，当文本篇幅不大且包含足够的必要信息、从而无需人为推断的时候。目前的人工智能技术也有可能极不稳定。例如，若是数据经过细微篡改，或者图像上叠加了一些随机噪点，那么人工智能工具的表现就会一塌糊涂（Marcus和Davis，2019）。[7]

2.2 人工智能底层技术简介

人工智能的每种应用都依赖一系列复杂的底层实现技术。这就要求人工智能工程师受过高阶数学、统计和其他数据科学以及编程等方面的训练。因为这些技术太过专业，无法在此深入探讨。[8] 于是，我们先来简要地介绍一些核心人工智能底层技术，然后介绍一些典型人工智能技术应用。

传统人工智能

比较早期的或“传统人工智能”（又称“符号人工智能”、“基于规则的人工智能”或“有效的老式人工智能”，即“GOFAI”）涉及编写如“若……则……（IF... THEN...）”语句序列以及其他条件逻辑规则等计算机完成指令需要采取的步骤。过去几十年里，随着医疗诊断、信用评级和生产制造等领域的广泛应用，此类基于规则的人工智能“专家系统”发展起来。这种“专家系统”是建立在一种名为“知识工程”的方法上。“知识工程”涉及解析和模拟某一具体领域的专家知识——这是一项资源密集型任务，但并非没有复杂的运算。典型的专家系统包含数百条规则，但是通常其逻辑尚算有迹可循。然而，随着各种规则之间的相互作用成倍增加，一旦想要修改或改进，那么对于专家系统来说是颇具挑战性的。

机器学习

从自然语言处理到人脸识别、无人驾驶汽车……许多新近的人工智能技术进步都离不开基于机器学习的计算方法。机器学习不去运用规则，而是分析大量数据，从中发现规律，在此基础上构建模型，用来预测未来数值。在这个意义上，与其说算法是预先设定好的，不如说算法是在“学习”。

机器学习方法主要有三种：有监督学习、无监督学习和强化学习。有监督学习涉及已有标记的数据，比如经人为标记的成千上万张人物照片。有监督学习将数据与标记关联起来，构建一个可用于类似数据的模型——比如，自动识别新照片中的人物。在无监督学习中，人工智能工具使用更海量的数据，不过这些数据没有经过归类或标记。无监督学习目的在于发现数据中的隐藏规律，即可用于对新数据进行分类的类簇（cluster）。例如，无监督学习方法可以寻找成千上万个例子中包含的规律，从中自动识别手写字母和数字。

图1：人工智能、机器学习、神经网络与深度学习之间的关系



不论在有监督还是无监督学习中，数据生成的模型都是固定的，而一旦数据有变，只好再次进行分析。然而，第三种机器学习方法强化学习涉及根据反馈不断完善模型——也即是说这个意义上的机器学习是指学习在持续进行中。在一些原始数据基础上，人工智能工具可以生成一个模型，然后被评为“正确”或“错误”，得到相应的奖励或处罚。人工智能工具利用这个强化机制来更新模型，然后再次尝试，进而在一段时间内迭代发展（学习和演进）。例如，如果一辆无人驾驶汽车规避一次碰撞，那么作为幕后功臣的模型会得到奖励（强化），加强自身未来规避类似碰撞的能力。

如今，机器学习非常普遍，导致它有时被视为人工智能的同义词，但其实它只是人工智能的一个子集。事实上，仍有许多人工智能应用并不采用机器学习方法，或者说，至少这些应用背后几乎总有某种有效的老式人工智能（基于规则的或符号人工智能）的身影。举个例子，许多常见的聊天机器人应用程序是预先设定好的，编入了人为定义的规则，预设好如何回复预期问题。其实，与比较早期的专家系统一样，

> **几乎每种大家如今见到的人工智能产品都需要人类专家直接输入内容。这个内容可能是来自语言学家和语音学家（在人工智能采用自然语言处理的情况下）、医师（在人工智能应用于医学领域的情况下）或道路交通与驾驶专家（在人工智能助力无人驾驶汽车的情况下）的专业知识，依此类推。若无有效的老式人工智能要素协助，机器学习无法创建完整的人工智能。（Sauberlich和Nikolic，2018）**

此外，应该认识到的重要一点是，机器学习即不是真的像人类学习一样，也不是独立地学习。相反，机器学习完全依赖于人：是人在选取、清理和标记数据；是人在设计和训练人工智能算法；也是人在管理、解读和评判输出结果。例如，有报道称，某种突破性的识物工具能够识别图片数据库中猫的图像，但事实上，这个系统仅可将看起来有一

定相似度的对象归为一类，而且需要人来识别这组对象是猫。同理，无人驾驶车辆上采用的机器学习方法完全依赖于人为标记好的千百万张街景图片。在很大程度上，硅谷将这项标记工作外包给了全球各地的人（采用亚马逊数据众标平台Turk[9]）和印度、肯尼亚、菲律宾以及乌克兰等国的企业。[10] 这些“新经济”工人的工作是手动跟踪和标记原型无人驾驶车辆捕捉到的视频中每帧画面里的对象（比如车辆、路标、行人等）——即机器学习算法下一步会分析的数据。

人工神经网络

人工神经网络（ANN）是一种灵感源自生物神经网络（即动物大脑）结构的人工智能技术。人工神经网络包含三类相互连通的人工神经元层：一个输入层、一个或多个隐藏的中间计算层以及一个产生结果的输出层。在机器学习过程中，赋予神经元连接的权重会在强化学习和“反向传播”环节中有所调整，方便人工神经网络计算新数据的输出值。一个人工神经网络应用的著名例子是谷歌的阿尔法围棋机器人（AlphaGo）。2016年，AlphaGo打败世界围棋冠军李世石。

隐藏的中间计算神经元层是人工神经网络能力大小的关键所在，但也会带来一个重大约束因素。人们通常没有办法质询深度神经网络，从而无法判定它是如何求解的。如此，决策背后的理由是不可知的。许多企业正在研究如何揭开和检视这些决策背后的机制（Burt，2019），使用户能够明白为什么一个给定算法会得出特定的决策。了解这种背后决策机制十分重要，尤其当人工神经网络和其他机器学习方法被用于会对人类产生重大影响的决策时，比如计算某人留在监狱中的时长。然而，这依然会使问题复杂化——“生成人工智能决策相关的更多信息或许会创造切实效益，但也会带来新的风险”（Burt，2019）。

深度学习

深度学习指包含多个中间层的人工神经网络方法。正是由于深度学习方法，近年来许多令人瞩目的人工智能应用才成为可能（比如，自然语言处理、语音识别、计算机视觉、影像创作、药物研发、基因组学等领域）。深度学习的新兴模型包括：所谓的“深度神经网络”（DNN）——找到有效的数学运算法则，将一项输入变成所需的输出；“循环神经网络”（RNN）——使数据可以流向任意方向，能够处理输入序列，可应用于语言建模等领域；以及“卷积神经网络”（CNN）——用于处理来自多数组的数据，比如使用三张二维图片形成三维计算机视觉。

最后，值得一提的是，许多近年来的人工智能技术进步（特别是围绕图像处理的方法）都是通过“生成式对抗网络”（GAN）实现的。在生成式对抗网络中，两个深度神经网络彼此竞争——“生成式网络”创建可能的输出，而“判别式网络”负责评价这些输出。由此产生的结果用于下一次迭代。例如，DeepMind公司的阿尔法元（AlphaZero）采用生成式对抗网络方法来学习如何玩赢若干棋盘游戏（Dong等人，2017）。另外，一种接受过照片训练的生成式对抗网络已经生成看似真人但并不存在的人物图像。[11] 这种方法的其他应用目前尚在研究中。

2.3 人工智能技术简介

上述所有底层技术共同催生了一系列人工智能技术应用。这些科技越来越多地以“人工智能即服务”的形式呈现出来（参见表1），也正广泛运用于上述大多数应用领域。具体人工智能技术（详见表2）列举如下：

■ 自然语言处理（NLP）

使用人工智能自动解读文本，包括进行语义分析（如在法律服务和翻译领域的应用）和生成文本（如在自动新闻领域的应用）。

■ 语音识别

将自然语言处理技术应用到口语上，包括智能手机语音功能、人工智能个人助理和银行服务中的对话机器人等。

■ 图像识别和处理

将人工智能用于人脸识别（如电子护照）、手写识别（如自动邮政分拣）、图像处理（如深伪技术）以及无人驾驶车辆等。

■ 自主代理

将人工智能应用于计算机游戏角色、恶意软件机器人、虚拟伴侣、智能机器人和自主战争等。

■ 情绪检测

将人工智能用于分析文本、行为和面孔中的情绪。

■ 用于预测的数据挖掘

将人工智能应用于医疗诊断、天气预报、业务预测、智慧城市、财务预测和诈骗侦测等领域。

■ 人工创作

将人工智能应用于可以创作新照片、新音乐、新艺术作品或新故事的系统。

表2：人工智能技术

人工智能技术	详情	主要底层技术	发展情况	示例
自然语言处理（NLP）	人工智能自动生成文本（如在自动新闻中）和解释文本，包括进行语义分析（如在法律服务和翻译中）。	机器学习（特别是深度学习）、回归分析和K均值算法。	自然语言处理、语音识别和图像识别均已达到90%以上的精确度。但是，有研究人员认为，即使有更多数据和更快的处理器，在新的人工智能范式发展起来之前，这项技术也不会有多大改进。	Otter[12]
语音识别	将自然语言处理技术应用到口语上，包括智能手机语音功能、人工智能个人助理和银行服务中的对话机器人等。	机器学习，特别是一种名为“长期短时记忆”（LSTM）的深度学习循环神经网络方法。		阿里云[13]
图像识别和处理	包括人脸识别（如电子护照）、手写识别（如自动邮政分拣）、图像处理（如深伪技术）以及无人驾驶车辆等。	机器学习，特别是深度学习卷积神经网络。		Google Lens[14]
自主代理	具体应用包括计算机游戏角色、恶意软件机器人、虚拟伴侣、智能机器人和自主战争等。	有效的老式人工智能和机器学习（比如，深度学习自组织神经网络、进化式学习和强化学习等）。	研究工作聚焦于涌现智能、协作活动、情境性和具身化等受相对简单生物生命形式启发的特性。	Woebot[15]
情绪检测	包括文本、行为和面部情绪分析。	贝叶斯网络和机器学习，特别是深度学习。	全球多种产品正在研发中，但这些技术的应用通常颇有争议。	Affectiva[16]
用于预测的数据挖掘	包括财务预测、诈骗侦测、医疗诊断、天气预报、业务流程和智慧城市等。	机器学习（特别是有监督学习和深度学习）、贝叶斯网络和支持向量机。	数据挖掘应用程序正在呈指数级增长，从预测购买行为到解读含噪脑电图（EEG）信号，应用颇广。	科研项目[17]
人工创作	包括可以创作新照片、新音乐、新艺术作品或新故事的系统。	生成式对抗网络（GAN）是一种涉及两个神经网络彼此对抗竞争的深度学习技术。 自回归语言模型采用深度学习算法来生成“类人”的文本。	生成式对抗网络是一项前沿人工智能技术，所以其未来应用发展缓慢，正在一点一点显露出来。 一种名为GPT-3的自回归语言模型可以生成令人惊叹的“类人”文本。但是，在表象之下，这个系统并不理解它所输出的文本。[18]	“此人不存在”网站[11] GPT-3（Brown等人，2020）

2.4 人工智能潜在发展趋势：“弱”人工智能与“强”人工智能

虽然人工智能科学家一开始是想要打造类人的通用人工智能（AGI），称为“强人工智能”，但第2.1节中的每种应用其实都是专用人工智能（ANI），也称“弱人工智能”（Searle, 1980）。每种专用人工智能应用涉及的领域均受到严格的约束和限制，而且无法直接应用于其他领域。例如，用于天气预报的人工智能无法预测股市波动，而用于驾驶汽车的人工智能无法诊断肿瘤。尽管这些应用程序不是人类意义上的“智能”，但是在效率和耐力上的表现往往胜人一筹，而且能够识别海量数据中存在的显著规律。

这些应用固然有一些引人瞩目的成就，但重要的是我们应该认识到，人工智能技术仍然处于起步阶段。例如，与我们的智能手机个人助理或其他智能家居设备进行真正的对话是不可能的事情，人工智能只会回应具体的命令，而且回答经常是错误的。也即是说，虽然人工智能在某些功能（如找出数据中的规律）方面的表现超越人类专家，但在其他方面（如进行深度对话），人工智能的表现甚至不如两岁孩童。[19] 此外，全球范围内种种迹象表明，与夸张预测相反，对人工智能技术的投资或许正在“降温”——虽然不至于迎来又一次人工智能凛冬，但是其许诺的潜力总是显得远在天边，可望而不可及（Lucas, 2018）。甚至有人表示，人工智能技术进步将趋于平缓（Marcus和Davis, 2019）。譬如，无人驾驶车辆安全穿梭于巴勒莫或德里街道的场景仍然是几十年以后才会发生的事情，而图像识别应用程序仍然易受愚弄（Mitchell, 2019）。

2.5 对人工智能潜能和局限性的批判性审视

从三类基本成就方面来审视人工智能或许会有助益:

- 代表“真实、迅速的技术进步”的人工智能技术，主要专注于“感知能力”，包括基于扫描的医疗诊断、语音转文本以及深伪技术等（Narayanan，2019）；
- “日趋完善”的人工智能技术，主要围绕自动判断，包括垃圾邮件及仇恨言论检测和内容推荐（Narayanan，2019）；
- “在根本上备受质疑”的人工智能技术，主要集中在预测社会结果，包括刑事累犯和工作绩效（Narayanan，2019）；

关键在于，虽然深度神经网络已经训练有素，能够完成一些不可思议的任务，但是有很多事情是它们无法做到的（Marcus和Davis，2019）。尤其是它们没有做真正智能的事情。其实，

> **这些技术只是从统计数据中归纳出规律。这些规律或许更加隐晦、更加间接并且比历史方法更加自动化，能够反映更加复杂的统计现象，但是仍然只是数学的化身，而不是有智力的实体，不论这些结果有多么令人惊叹。（Leetaru，2018）**

此外，多项研究已经表明，若是机器学习方法涉及成千上万个数据变量或功能，因而需要大量资源和能源来进行计算，那么与仅使用少数功能且能耗少得多的简单线性回归方法相比，这些复杂方法或许好不了多少（Narayanan，2019）。

尽管如此，与以往技术革命相比，如今人工智能技术的突出之处在于它的发展速度和普遍性：速度快到几乎每天都会涌现出新技术和转型方式，并且几乎影响着现代生活的每个方面。在这里仅举一个令人瞩目的例子：研究人员已经开发出一个使用三个深度学习网络、表现胜过人类专家的乳腺癌预测人工智能系统（McKinney等人，2020）。

无论如何，有证据表明，在许多情况下机器学习取得的成就被略微夸大了，而我们见到的快速进步或许即将达到上限。例如，纵然机器学习技术取得了一些非凡成就，但认为机器学习如今能与人一样准确识别图片中物体的说法存在两个局限性：一是这些技术依赖系统访问千百万张已标记图片——而一个小孩子只需几张图片即可达到同样的准确度；二是对准确度的解释太过宽松——在某个最广为人知的机器视觉竞赛中，只要人工智能工具的五条建议中有一条是正确的，即判定为成功（Mitchell，2019）。再者，如前文所述，目前推动重大人工智能技术进步的全部底层技术（比如，深度神经网络和机器学习）皆是早在几十年前就已经发展起来。换言之，虽然我们继续见到现有技术和新兴应用发生迭代改进，但我们仍然在等待下一个重大突破。

有专家认为，只有当“传统人工智能”或“有效的老式人工智能”的符号或基于规则的底层技术与数据驱动型方法结合起来时，才会发生这样的重大突破。其实，这种重大突破已经发生了，以无人驾驶车辆为例：

> **有一些事情需要智能代理来做，毕竟深度学习技术目前并不是很擅长这些。譬如，它不是很擅长抽象推断。它也不是很擅长处理不曾见过、信息掌握相对不完整的情况。因此，我们需要用其他工具来补充深度学习技术……在我看来，我们需要结合使用符号处理技术（即基于规则的人工智能）和深度学习技术。太长时间以来，这两种技术一直被割裂地看待。（Marcus，接受福特汽车的访谈，2018，第318页）**

2.6 人机协同智能

人工智能技术诞生于对人类思维过程的模拟和机械化尝试（Turing，1950），并且自诞生以来就处于与后者不稳定的关系当中。有意思的是，尽管我们经常读到有关人工智能技术取得卓著成就的报道（从在游戏中打败人类，到比人类更加准确地读取视网膜扫描），但当前人工智能技术方法的局限性也变得日益明显（Mitchell，2019）。事实上，虽然人工智能已经很擅长那些对人类来说具有挑战性的工作流程（比如，规律识别和统计推理），但是在其他对人类来说相对容易的流程上（比如，自主学习、常识和价值判断），它仍然很弱。这即是莫拉维克悖论（Moravec's paradox）：

> **要让计算机在智力测验或下棋方面表现出成人水平，是相对容易的事，但要赋予它们一岁幼儿的感知能力和肢体动能，却是不易或不可能的事。（Moravec，1988，第15页）**

此外，如前文所指出的，人类对于人工智能技术成功的关键作用通常被忽视了。大多时候，人工智能需要人来执行各种任务：建构问题；阐述问题；选取、清理和标记数据；设计或选择算法；决定组合方案；根据数值得出结论或做出判断……不胜枚举。相应地，虽然许多任务有望实现自动化，但人类仍然需要发挥一些关键作用，而我们要为此做好准备（Holmes等人，2019）。

事实上，人类与人工智能之间的关系越来越复杂微妙，导致有人呼吁重新构建或重新命名人工智能，将其称为“增强智能”（augmented intelligence）（Zheng，2017）。

例如，虽然计算机如今可以在下棋上打败人类，但是人机协同似乎更有成效——比人或计算机独自工作更佳。在竞赛中，业余棋手借助人工智能已经能够打败计算机或大师级棋手（Brynjolfsson和McAfee，2014）。这个做法涉及使用人工智能技术来增强、而非篡夺人类能力。向增强智能的转变使得各方注重开发能够补充和扩展人类认知的人工智能技术，揭示了人类与人工智能更加有效地协同的途径，引发了应该在人机之间如何进行任务分工的思考，以及指向一个有吸引力的可能性——通过审慎地结合使用人工智能与群体智能，人们或许能够应对当今世界面临的各种问题（Mulgan，2018）。

2.7 第四次工业革命和人工智能对就业的影响

人们认为，人工智能是第四次工业革命（“工业4.0”）的一个关键使能因素。

> **在我们现今面临的多种多样而又令人着迷的挑战中，最迫切、最重大的挑战是如何认识和影响新一轮科技革命，这涉及颇多，复杂程度不亚于人类大转变。（Schwab，2017，第1页）**

工业4.0技术包括3D打印、无人驾驶车辆、生物技术、纳米技术、量子计算、机器人学以及物联网等。这些技术全都是人工智能支撑的。事实上，在现代工作场所，人工智能已经无处不在——从制造业到银行业、建筑业、交通运输行业等等，影响甚广，需要全系统策应。不可避免地，失业会增加，而新的职业也会增加。一个最近的全球性估计表明，到2030年，30%的工作可以实现自动化。届时，全球多达3.75亿名工作者可能面临失业。不论是蓝领工人还是白领员工，都会受到影响，而且首当其冲的并不一定是蓝领工人。

> **那些需要逻辑和代数等新近演化技能的工种是容易被人工智能复制和取代的。这些大多是中等收入的工作。相反，那些依赖移动和感知等深度演进技能的工作，则不是人工智能能够轻易复制取代的。这类工作通常收入较低。因此，人工智能正在掏空中等收入工作，而维持大量低收入工作。（Joshi，2017，©卫报新闻传媒有限公司版权所有）**

然而，与此同时，人工智能和其他前沿技术正在增加各种高技能工作——需要独特的创造力和分析能力以及人类互动。简而言之，许多工人的工作可能会消失，并且这些群体需要发展新的技能——提升技能（upskilling）或再训技能（reskilling），使自己能够胜任人工智能带来的新职业。教育部门和培训机构等需要预期这种变化，使如今的工作者和新一代工作者均具备必要的技术性和社交性工作技能，从而平稳过渡到一个人工智能主导的世界，同时确保社会可持续发展。

其实，全球各国政府部门纷纷已经开始制定战略计划来应对未来人工智能技术。以美国为例，《国家人工智能研究与发展战略规划》（国家科技委员会，2016）倡导在各种人工智能技术理论和实践上进行长期投入和研究。这些人工智能技术具体包括数据分析、人工智能感知、理解人工智能的理论缺陷、通用人工智能、可扩展人工智能、人工智能驱动的类人机器人、能感知人类的人工智能（human-aware AI）以及人类机能增强（human augmentation）等。2017年，中国政府发布《新一代人工智能发展规划》（中华人民共和国政府，2017）。同样地，这份规划侧重一系列理论性和实操性的人工智能技术，包括大数据智能、跨媒体智能、人机混合增强智能、群体智能、自主智能、高级机器学习、类脑智能以及量子智能等。更重要的是两国的人工智能战略规划均强调人和人工智能系统无缝交互的潜力，而且二者均旨在实现人工智能的潜在社会经济效益，同时尽量减少其负面影响。

3. 理解人工智能与教育：新兴实践与效益风险评估

人工智能在教育领域的应用可以追溯至20世纪70年代。当时，研究人员感兴趣的是见证计算机如何取代一对一人工辅导——被视为最富有成效、但大多数人难以获得的教学方法（Bloom，1984）。早期研究工作采用基于规则的人工智能技术来为每位学员自动调整或定制学习（Carbonell，1970；Self，1974）。从一开始，人工智能在教育领域的应用便朝着多个方向发展，首先是面向学生的人工智能（为支持学习和测评而设计的工具），然后纳入面向教师的人工智能（为支持授课而设计），还有面向系统的人工智能（为支持教育机构管理而设计）（Baker等人，2019）。实际上，人工智能与教育之间的互动不止如此，除了课堂上的人工智能*应用*（即“*使用*人工智能学习”），还会教授人工智能技术相关知识（即“*学习*人工智能”）以及帮助公民准备好应对人工智能时代的生存技能（即“*为了*人机协同而学习”）。同时，人工智能在教育领域的应用让人关注教学法、组织结构、可获取性、伦理规范、公平性和可持续性等问题——要想使一项工作实现自动化，人们首先需要全面透彻地了解它。

再者，想要人工智能支持教育可持续发展的潜力得以充分实现，还需要识别和利用人工智能工具的全部可能效益，同时承认并化解相应的风险。因此，相关方还需要持续审视教育组织方式，这或许意味着从根本上重塑教育的核心基础，实现可持续发展目标4这一核心目的。我们还需要了解人工智能在教育领域的应用会有怎样的成效：人工智能可以带来哪些切实效益？我们如何确保人工智能满足实际需要，而不是风靡一时的最新教育科技风潮？我们应该允许人工智能做些什么？

为了充分释放机遇、化解潜在风险，我们需要针对下列关键政策问题的进行全系统响应：

1. 如何借助人工智能强化教育质量？
2. 如何确保人工智能在教育中应用的伦理规范、包容性和公平性？
3. 教育如何帮助人类做好与人工智能共生协作的准备？

为帮助教育体系应对这些复杂挑战，联合国教科文组织与中国政府携手在北京主办“国际人工智能与教育大会”（2019），主题是“规划人工智能时代的教育：引领与跨越”。这届大会的参与者包括50多位政府部长和副部长以及来自100多个教科文组织成员国、联合国机构、学术机构、公民社会组织和私营部门组织的大约500名国际代表。参会人员探讨了在“可持续发展目标4–2030年教育和2030年以后未来教育”背景下，人工智能的全系统影响。这次大会的关键成果是《北京共识——人工智能与教育》（联合国教科文组织，2019a）。该文件就上述三大政策问题相关的关键议题和政策建议达成共识。《北京共识》中提出的主要建议已穿插引用在本出版物之中。

本章余下内容将论述影响教育领域人工智能应用的主要趋势和问题，以及效益风险分析及其对政策应对的启示。

3.1 如何借助人工智能强化教育质量？

过去十年里，使用人工智能工具支持或加强学习的做法呈指数级增长（Holmes等人，2019）。而在新冠肺炎疫情学校封闭期间，这一趋势有增无减。不过，人工智能在提高学习效果方面的表现如何？人工智能是否有助于学习科学工作者和从业人员深入探析有效学习背后的机制？关于这两个问题，我们掌握的证据仍然稀少（Zawacki-Richter等人，2019）。

> **在认为人工智能在教育领域的应用具有革命性潜力的说法中，有许多都建立在猜想、推测和乐观主义的基础上。（Nemorin，2021）**

而且，我们尚未探索人工智能在其他应用方面的潜力，包括追踪不同环境下的学习成果、评估学习能力（尤其是在非正规和非正式环境中习得的能力）等方面。

在其他文献中，教育人工智能应用被分为三大类别：面向系统的、面向学生的以及面向教师的（Baker等人，2019）。然而，对政策制定者来说，我们按四种需要将新兴和潜在人工智能应用分为四大类别：(i) 教育管理和供给；(ii) 学习和测评；(iii) 赋能教师和提高授课质量；以及 (iv) 终身学习。针对每个类别，我们将给出一些典型例子。有一点很重要，那就是承认这些拟议类别之间存在固有的相互关联，而且人工智能在教育领域的应用潜能可能不只是满足单方面的需要，例如，教辅应用程序在设计上可能同时为师生提供支持。另外，我们还提议，人工智能技术在教育领域的应用规划和政策应该基于中长期的当地需要，而不是基于整个市场，同时应该以效益风险分析为依据，然后方可大规模地采用这些技术。尤其值得一提的是，虽然支持者指出人工智能为疫情期间学校封闭导致、转变为在线学习形式的问题提供了一个现成的解决方案，但是目前鲜有证据表明这个做法是适当或有效的。

利用人工智能支持教育管理和教育供给

人工智能技术正越来越多地应用于促进教育管理和教育供给。这些面向系统的应用并不直接支持教学，而是旨在实现学校行政管理各个方面的自动化——建立在教育管理信息系统的基础之上（Villanueva，2003），涵盖招生、排课、考勤、作业监测以及校务监管等。有时，名为“学习分析”的数据挖掘方法（du Boulay等人，2018）被用来分析学习管理系统生成的大数据，为教师和学校管理人员提供相关信息，偶尔也向学生提供指导。例如，有的学习分析工具预测哪些学生有不及格的风险。这种分析的输出通常是以虚拟“仪表盘”报告的形式呈现（Verbert等人，2013），用来辅助数据驱动型决策过程（James等人，2008；Marsh等人，2006）。从教育体系得来的大数据也有助于教育供给方面的政策制定：

> **公立教育机构越来越多地使用大数据来创建数字化、交互式的数据可视化工具，在此基础上为政策制定者提供教育体系的最新信息。（Giest，2017，第377页）**

例如，若是为难民而设的学习管理系统，其数据输出可能有助于确定提供教育机会和支持的最优方式。事实也表明，根据对学习者个性化需要和学习水平的分析，人工智能能够有效管理不同平台的学习内容。譬如，一个项目的目标是管理成千上万个开放教育资源，使之更容易被全体学习者获取（Kreitmayer等人，2018）。

然而，要使任何基于数据的分析工具有用、使其结论值得信赖且兼顾公平，原始数据及其代理指标必须准确无误、不偏不倚、不存在糟糕假设，同时采用的计算方法也必须适当且稳健——这些要求看似简单，但经常没有得到严格遵守（Holmes等人，2019）。无论如何，总有人工智能技术公司收集大量学生互动数据，只是为了使用机器学习方法“寻找规律”。这么做的目的是训练软件识别哪些孩子感到困惑不解或枯燥乏味，在此基础上提高学生的学习水平，使他们更加投入课堂。尽管如此，这一做法颇有争议。人们将这种数据采集称为“边缘型心理健康评估……助长将孩子们看作需要治疗的潜在病人的风气”（Herold，2018）。

在某些情况下，这类人工智能工具也被用于监测学生在课堂上的注意力（Connor，2018），也有其他工具被用于跟踪学生出勤情况（Harwell，2019）和预测教师的授课表现，这产生了令人担忧的后果（O'Neil，2017）。上述这些面向系统的应用存在的问题应该被纳入关于人工智能与教育的更广泛讨论。

有前景的案例

- 教育聊天机器人：聊天机器人是利用云服务和人工智能方法与人进行模拟对话的在线计算机程序。人类用户键入或说出一个问题，然后聊天机器人给予回答，提供相关信息或执行某项简单任务。聊天机器人有两个复杂层次。大多数聊天机器人运用规则和关键词来选取预设脚本的回答，而虚拟助手聊天机器人（比如Siri[20]、Alexa[21]、DuerOS[22]和小艺[23]）采用自然语言处理和机器学习方法来生成独特的回答。在教育领域，聊天机器人正应用于越来越多的应用程序之中。具体用途包括促进招生工作（比如，“贵校有哪些计算课程？”）；提供7×24全天候信息服务（比如，“我应该哪天交作业？”）；以及直接支持学习（或许纳入基于对话的导学系统的一部分或采用了基于对话的智能导学方法，参见第17页，使学生投入口语对话或提供自动反馈）。教育聊天机器人有Ada[24]和Deakin Genie[25]等。

- OU Analyse[26]是一款英国开放大学设计的人工智能应用程序，用来预测学生成绩和识别存在不及格风险的学生，具体手段是分析该校教育管理信息系统（EMIS）提供的大数据。这些预测结果可供课程指导老师或支持团队使用，并且采用易于获取的仪表盘报告形式，方便使用者考虑最适当的支持。总体目标是帮助有困难的学生完成课程学习（Herodotou等人，2017）。

- “Swift”是印度在线学习服务机构Swift eLearning Services开发的一套方法，可以使教育管理信息系统利用在线学习模块中生成的数据。[27] 从学习者互动中收集而来的数据可以提供宝贵洞见，帮助了解学习者何时表现差劲或优异以及背后的原因。分析这个数据有助于根据学习者偏好量身打造个性化的学习路径。

《北京共识——人工智能与教育》

10. 意识到应用数据变革基于实证的政策规划方面的突破。考虑整合或开发合适的人工智能技术和工具对教育管理信息系统（EMIS）进行升级换代，以加强数据收集和处理，使教育的管理和供给更加公平、包容、开放和个性化。

11. 还考虑在不同学习机构和学习场境中引入能够通过运用人工智能实现的新的教育和培训供给模式，以便服务于学生、教职人员、家长和社区等不同行为者。

（联合国教科文组织，2019a，第5页）

- 美国的ALP[28]系统提供后台人工智能功能来支持标准教育技术。该系统分析用户数据，将其聚合，为每名学生的互动、偏好和成绩创建心理测评档案。

- UniTime[29]是一个以美国为主、另有四大洲的组织参与的项目。该项目是一个综合人工智能赋能教育调度系统，可以为高校课程制定时间表、管理上课时间和教室变更以及提供学生的个人课程表。

利用人工智能支持学习和测评

以面向学生为主的人工智能技术应用最受研究人员、开发者、教育工作者和政策制定者的关注。这些应用被视为“第四次教育革命”的一部分（Seldon和Abidoye，2018），旨在为每位学习者提供优质、个性化和无处不在的终身学习（正规、非正规以及非正式）机会，不论他们身在何处。人工智能也有望催生新的测评方法，比如人工智能赋能的自适应测评和持续测评等（Luckin，2017）。不过，有一点很重要，那就是一开始即承认，利用人工智能支持学习和测评也会带来各种各样的问题，而这些问题尚未得到妥善解决。具体包括对教学法的担忧，缺乏有力证据表明人工智能技术的效果和对教师角色的潜在影响，还有更加广泛的伦理问题（Holmes等人，2018b，2019）。

智能导学系统

出于若干原因，在这一节的论述中，我们首先来介绍一些“智能导学系统”（ITS）工具。在所有人工智能教育应用程序中，智能导学系统既具有最长的研究历史（超过40年），也是教育领域最常见的人工智能应用程序，同时它的学生受众人数也是最多的。此外，多年来，这些系统吸引了最高水平的投资和关注度，备受世界上领先科技公司的青睐，而且，全球各地的教育体系一直采用这些系统，学生用户群体数以百万计。

总的来说，智能导学系统的工作机制是：围绕数学和物理等结构化科目中的议题，为每位学生提供个性化的分步教程。系统会借鉴相关科目和认知科学的专家知识，通过各种学习资料和活动决定学生的最优学习路径，同时针对个别学生的误解和成就做出回应。有时，这种方法也被用于学习管理系统中，比如Moodle[30]和Open edX[31]等，以及可汗学院等平台[32]。

在学生参与学习活动的过程中，系统会采用知识追踪[33]和机器学习方法，根据个别学生的优劣势自动调整难易水平并给予提示或指导——一切只为确保学生能够高效地学习相应主题。有的智能导学系统也捕捉和分析学生情绪状态的相关数据，包括通过监测学生的目光来推断他们的专注水平。

不过，虽然这看起来颇有吸引力，但是需要认识到，智能导学系统中所体现的假设和典型的指令式知识传播教学方法存在局限性，忽视了学习科学重视的其他方法带来的可能性，比如协作学习、引导性发现式学习（guided discovery learning）和从错误中学习（productive failure）等（Dean Jr.和Kuhn，2007）。其中，智能导学系统提供的“个性化学习”功能一般仅支持规定内容学习路径的个性化，而非通过将学习结果个性化和赋能学生实现自己的个人抱负，以此促进学生的能动性。此外，虽然有的研究结果表明，研究人员设计的某些智能导学系统可以媲美课堂教学（比如，du Boulay，2016），而且尽管全球各地许多教育体系已经引入这些系统，但其实目前缺乏有力证据证明这些商业智能导学系统如开发者说的那么卓有成效（Holmes等人，2018a）。

智能导学系统的大量应用也引发其他问题。例如，这些系统往往会减少师生之间的人际交往。另外，在典型的智能导学系统课堂上，教师通常花费大量时间在办公桌前，方便监测关于学生互动的仪表盘报告。如果教师选择在室内四处走动，像在非智能导学系统课堂上一样，那么他们会错失了解学生上课情况的机会，难以决定何处应该给予个别关注。为了解决这个难题，一个名为Lumilo的智能导学系统（Holstein等人，2018）采用增强现实（AR）智能眼镜，让学习动态（比如误解）或行为（比如注意力不集中）信息“飘浮”在每个学生的头上，以便教师掌握详细且持续的信息，在此基础上采取相应行动。这是人工智能技术的一个吸引人心的应用，但值得注意的是，它旨在解决的问题纯属是由另一种人工智能技术应用引发的。另一方面，这种做法会造成人权（尤其是隐私权）等问题。

全球范围内，现今共有60多个可用的商业智能导学系统，包括Alef[34]、ALEKS[35]、Byjus[36]、Mathia[37]、Qubena[38]、Riiid[39]和松鼠AI[40]。教科文组织教育委员会目前正在越南学校里测试一种名为“高科技 高感触（Hi-Tech Hi-Touch）”[41]的方法，致力于最大化地发挥的智能导学系统和教师的作用。

基于对话的导学系统

基于对话的导学系统（DBTS）采用自然语言处理和其他人工智能方法，模拟人类辅导教师与学生之间在按部就班完成线上任务过程中的口头辅导对话，很多时候涉及计算机科学议题，不过，最近通常涉及不那么结构化的领域。基于对话的导学系统采用苏格拉底式辅导法，即探究人工智能生成的问题，而不是采用授课式教学，在发展对话过程中，引导学生自己去找到某个问题的合适解决方案。这种方法旨在鼓励学生参与共建解释，形成对一个议题的深层理解，而不是肤浅认识——某些授课式智能导学系统可能导致这种表浅认识。

目前，在用的基于对话的导学系统相对较少。使用这些系统的大多是研究项目团队。其中，最经得起考验的系统是AutoTutor（Graesser等人，2001）。Watson Tutor[42]是由IBM公司和培生教育出版集团联合开发的一款商业系统。

探索性学习环境

不同于智能导学系统和基于对话的导学系统的按部就班思路，探索性学习环境（ELE）提供了一种替代范式。探索性学习环境采用建构主义理念：不去遵循按部就班的顺序，比如智能导学系统青睐的“知识传播”模式，而是鼓励学生积极探索学习环境，将之与自己的已有知识架构连接起来，从而构建自己的知识体系。在探索性学习环境中，人工智能的作用是在知识追踪和机器学习方法的基础上，提供自动指导和反馈，从而减少探索式学习通常会产生的认知过载的问题。这种反馈可以消除各种误解，并提出替代方法，在学生进行探索时提供支持。

从广义上讲，探索性学习环境还未走出研究实验室。例如“ECHOES”（Bernardini等人，2014）；“Fractions Lab”（Rummel等人，2016）；以及“Betty's Brain”（Leelawong和Biswas，2008）。

作文自动评阅

作文自动评阅（AWE）并非是让学生在电脑前直接接收即时的指导，而是利用自然语言处理和其他人工智能技术提供作文的自动反馈。总体而言，有两种相互重叠的作文自动评阅方式：形成式作文自动评阅会让学生在提交作文之前提出建议，帮助完善其作文；总结式作文自动评阅则会辅助自动评分。

事实上，多数作文自动评阅系统更注重评分，而非反馈；其设计目的主要是降低评估成本，因此可能被视为一种面向系统的应用程序组件。但是，自引入以来，总结式作文自动评阅一直备受争议（Feathers，2019）。例如，这种方法一直受到批评是因为它根据句子长度等表面特征为学生评分，即使文章内容毫无意义——学生可以胡编乱造地糊弄。另外，系统也无法评估创意性。最令人担忧的是，作文自动评阅系统依据的算法有时存有偏见，特别是对于少数民族学生，这可能是由词汇和句子结构的不同使用方式造成的。总结式作文自动评阅系统也没有解决易于获取的“深度伪造”大学及中小学作业问题——通过借鉴专业领域知识并模仿学生个人的写作风格，由人工智能技术撰写的文章。这些情况很难发现。[43]最后一点，使用人工智能为作业评分，也不能表明评分的价值。虽然评分过程耗时又枯燥无味，但这也是老师了解学生能力的最好机会。

然而，一些面向学生的作文自动评阅系统优先考虑的是给予可操作的反馈——帮助学生提高写作水平，推进学生的自主学习和元认知等高阶过程。

形成式和总结式的作文自动评阅系统目前通过各种程序（例如WriteToLearn[44]、e-Rater[45]、和Turnitin[46]）应用于多种教学场景。另有一种相关方法，采用人工智能将新的学生表现与大量的已受评估的既往学生的表现进行比较，目前已经用于评价音乐表演，例如使用程序Smartmusic[47]进行评价。

人工智能支持的阅读和语言学习

阅读和语言学习工具正越来越多地使用人工智能来增强其方法。例如，一些工具使用智能导学系统的路径个性化设置以及人工智能驱动的语音识别。通常，语音识别用于将学生的语音与母语人士的样本录音进行比较，以提供自动反馈，帮助学生改善发音。自动翻译的其他用途包括帮助学生阅读其他语言的学习材料，以及使来自不同文化背景的学生更容易相互交流。同时，其他系统还会检测并自动分析阅读技能，从而为学生个人提供反馈。

阅读和语言学习的人工智能应用程序包括人工智能Teacher[48]、Amazing English[49]、Babbel[50]和Duolingo[51]。

智能机器人

目前也在探索如何将人工智能驱动的或“智能”机器人应用于教育（Belpaeme，2018），特别是在学习环境中存在有学习障碍或困难的儿童。例如，目前已经为自闭症谱系障碍学习者创造出具有语音功能的仿人机器人，提供可预测的机械互动，而不是人类的互动，因为后者往往让这些学习者感到困惑。开发此类机器人的目标在于发展学习者的沟通和社交技能（Dautenhahn等人，2009）。另外还有远程临场机器人（telepresence robots）——因患病或因人道主义或难民危机而无法上学的学生可以通过远程临场机器人重返课堂。[52] 第三个例子是使用仿人机器人向幼儿介绍计算机编程和其他STEM科目，例如新加坡幼儿园课堂使用的Nao[53]或Pepper[54]（Graham，2018）。

可教代理（Teachable agents）

人们早就知道，向他人传授某些内容时，自身可以更深刻地习得并掌握该项内容（Cohen等人，1982）。不少人工智能方案也利用了这一特点。例如，前面提到的探索性学习环境（Betty's Brain）就鼓励学生向一个叫Betty的虚拟学生教授关于河流生态系统知识。另有一个来自于瑞典研究项目的案例：学生通过教授一个虚拟的可教代理关于数学的益智游戏规则（Pareto，2009）。第三个案例来自于瑞士：是幼儿教授一个仿人机器人如何写字[55]——这种方法可以刺激元认知、同理心和自尊的发展（Hood等人，2015）。

教育虚拟现实及增强现实

虚拟现实（VR）和增强现实（AR）是两种相关的创新技术，已经应用于教育领域，通常与机器学习和其他人工智能技术相结合，以增强用户体验。虚拟现实技术已被用于K-12及其他年级许多科目的教学中，包括天文学、生物学和地质学。虚拟现实眼镜可提供一种隔绝物理世界的沉浸式体验，使用户感觉仿佛被送到了一系列真实世界或想象环境中（如火星表面、火山内部或有胎儿正在发育的人类子宫）。部分虚拟现实创新项目使用人工智能技术控制逼真的虚拟化身，利用自然语言处理进行语音控制，或通过几张起始图像生成整个环境。

而增强现实技术则是将计算机生成的图像叠加在用户的现实世界视野上（很像战斗机飞行员的抬头显示器）。Lumilo正是采用上述增强现实方法，将学生的智能导学系统表现信息浮现在学生头顶上方。当智能手机的摄像头对准某个二维码时，可能会显示出增强现实三维人体心脏，对此可以进行深入探索。增强现实技术还可能涉及人工智能驱动的图像识别和追踪。利用这项技术，可以在部分手机和Instagram或Snapchat等网站上将兔子耳朵或猫的胡须放在人的图像上。虚拟现实和增强现实应用于教育领域的实例包括Blippar[56]、EonReality[57]、Google Education[58]、NeoBear[59]和VR Monkey[60]。

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13. 在教师政策框架内动态地审视并界定教师的角色及其所需能力，强化教师培训机构并制定适当的能力建设方案，支持教师为在富含人工智能的教育环境中有效工作做好准备。

14. 认识到人工智能在支持学习和学习评价潜能方面的发展趋势，评估并调整课程，以促进人工智能与学习方式变革的深度融合。在使用人工智能的惠益明显大于其风险的领域，考虑应用现有的人工智能工具或开发创新性人工智能解决方案，辅助不同学科领域中明确界定的学习任务，并为开发跨学科技能和能力所需的人工智能工具提供支持。

16. 应用或开发人工智能工具以支持动态适应性学习过程；发掘数据潜能，支持学生综合能力的多维度评价；支持大规模远程评价。

（联合国教科文组织，2019a，第5-6页）

学习网络协调器

学习网络协调器（LNO）能够使学生和教师互联，参与学习和组织学习活动。学习网络协调器通常根据参与者的参与安排、学科领域和专业知识进行匹配，并能够促进协调和合作。例如“第三空间学习（Third Space Learning）”[61]，将潜在数学不及格的英国小学生与其他国家的数学老师相连接。另一个例子是“智能学伴（Smart Learning Partner）”[62]，其使用的人工智能驱动平台使学生能够通过手机像交友软件一样选择真人教师并与之连接，从而获得一对一的支持。

人工智能支持的协作学习

协作学习，即学生共同解决问题，可提高学习效果（Luckin等人，2017），但是学习者之间很难实现有效的协作。人工智能可以通过各种方式转变协作学习：一种可以帮助学习者之间远程连接的工具；可以识别最适合特定协作任务的学生，并对其进行相应分组；或者可以作为虚拟代理，促进小组讨论。虽然尚未发现具体实例，但目前已经成为一种研究方向（例如Cukurova等人，2017）。

人工智能为教师赋能并提高教学水平

尽管面向教师的人工智能应用具有增强教师能力的潜力，但迄今为止利用这些应用来增强和提高教师和教学受到的关注远远少于面向学生的人工智能。从定义上来说后者是取代了教师。目前，研究人员和开发者针对教师的设计往往只在结束之时，例如，在仪表盘中添加显示智能导学系统学生数据的功能。不过，目前已经慢慢开始解决这个问题。

许多面向教师的人工智能应用旨在通过自动化任务，如评估、剽窃检测、管理和反馈，帮助教师减少工作量。人们常常认为，这应该为教师腾出时间来投入到其他任务中，例如为个别学生提供更有效的支持。然而，随着人工智能的发展，教师有可能从更多任务中解脱出来，以至于对教师的感知需求减少到几乎没有。虽然这在教师稀缺的情况下可能会有一些好处，但消除对人类教师的需求这一目的表明对教师在学习过程中的基本社会角色存有根本性的误解。

尽管如此，人们普遍认为，随着人工智能工具在课堂上的普及，教师的角色可能会发生变化。目前尚不清楚这将如何发生。不过，我们知道，教师必须培养新的能力，才能够与人工智能有效合作，另外，教师还需要适当的专业发展，以培养其人类和社会能力。

人工智能驱动的讨论论坛监控

人工智能技术正被用于支持在线教育，特别是帮助教师或服务商监控异步讨论论坛。在这些讨论论坛中，学生对给定的任务做出回应，向教师询问课程材料，并参与协作学习。这通常会产生大量帖子，所有这些帖子都必须经过审核和处理。人工智能可以通过多种方式提供帮助：一种工具可以对论坛帖子进行分流，并自动回应较简单的帖子；将提出重叠问题的帖子汇总；或使用情感分析来识别显示消极或无效情绪状态的帖子。这些技术结合起来，也可以使人类教师随时了解学生的意见和共同烦恼。例如，由美国佐治亚理工学院开发的人工智能助手Jill Watson（尽管存在一些伦理问题）主要是被用于分流论坛帖子并尽可能回答问题（如“什么时候提交作业？”），同时将其他更复杂的帖子交给人类教学助理。该人工智能助手是基于IBM的Watson平台，可自动回答一些学生问题，并向学生发送关于作业的电子邮件（Goel和Polepeddi，2017）。虽然人们认为这是一个成功的软件，但它延迟回复、幽默对话等特征使学生误认为人工智能助手是一个真正的人——因此在伦理层面受到了批判。

人工智能与人类的“双师”模式

虽然有一些明显的例外，但许多教育领域的人工智能——无论是否有意——都取代了一些教师任务，而不是协助教师更有效地教学。中国偏远农村地区的一些学校已经采用了所谓的“双师模式”。在这种方法中，一位专家教师通过视频连线为远程教室中的学生授课，而经验不足的当地教师则为学生提供额外指导（iResearch Global，2019）。未来人工智能教学助手或许可以为其中的某一角色提供支持。人工智能可以帮助人类教师完成许多任务，包括提供专业知识或专业培养资源，与特定环境内外的同事合作，监测学生表现，并在一段时间内跟踪进步情况。教授什么以及如何教学生仍然是教师的责任和特权。人工智能工具的作用仅仅是使教师的工作更容易、更学院化。例如乐外教（LeWaijiao）人工智能教室[63]，专门为人类教师提供支持，使其可以完成所有关键任务。

人工智能驱动的教学助理

如前所述，许多技术的设计目的是为了让教师从耗费时间的活动中解脱出来，如考勤、批改作业和反复回答同样的问题。然而，这样一来，这些技术实际上“接手”了大部分教学工作（有些声称可以比教师更好地提供个性化学习活动），干扰了师生关系，可能会使教师沦为功能性角色。例如，作文自动评阅系统的一个目的是减轻教师的评分负担。然而，正如我们所指出的一样，虽然评分工作可能很繁重，但它往往是教师了解学生策略和能力的一个重要机会。如果使用作文自动评阅系统，这一点就会丧失。

此外，这种方法显然低估了教师的独特技能和经验，以及学习者的社会和指导需求。人工智能不仅仅是使基于计算机的教学自动化，还有助于开创难以实现的新的教学方式，或者挑战甚至破坏现有教学法。这种方法旨在增强教师的专业知识，也许是以人工智能教学助理（AI TA）的方式（Luckin和Holmes，2017）。一些人工智能应用是为了对教师和学校赋能，以促进学习的转变。目前对这些应用程序已经进行了一些研究，但在真正利用这些应用程序之前，还需要克服许多技术和伦理问题。

3.2 如何挖掘人工智能的创新应用实现教育共同目标?

如上所探讨，人工智能正以多种方式用于教育领域。但是，尽管使用了尖端技术，这些应用程序也仅仅只是将一些过时的课堂实践自动化，而不是利用人工智能的独特能力重新构想教学与学习。换言之，教育领域的人工智能研发人员目前只是专注于仍较复杂但相对容易解决的知识记忆和回忆问题。而关于解决更复杂教育问题的可能性，如协作学习或新的评估和认定方式，尚未进行充分研究，更不用说作为商业产品大规模提供了。因此，为了促进对话，这里提出了一些可以利用人工智能实现教育领域共同利益的创新方法。

人工智能驱动的终身学习伙伴

每个学生都希望拥有自己的个性化终身导师，这也是最早激发人工智能应用于学习中的原因。从技术上讲，利用智能手机和相关技术的功能创造一个人工智能驱动的学习伙伴，使其能够终身陪伴个人学习者，并不一定很困难。学习伙伴不是以指令性智能导学系统的方式来教授学生，而是根据学生个人的兴趣和目标提供持续支持，帮助学生决定学习什么，以及在哪里和如何学习。它还可以引导学生沿着个性化的学习路径学习，帮助学生实现新目标，并将学生学习兴趣和成绩联系起来，同时鼓励学生反思和修改其长期学习目标。然而，尽管潜力深厚，但目前还没有商业化的人工智能终身学习产品，相关研究也很少。

人工智能赋能持续评估

虽然没有什么证据表明高利害考试（high-stakes examination）的有效性、可靠性或准确性，但在世界各地的教育系统中高利害考试都处于核心地位。因为有这样的考试，各大学和中小学往往实施应试教学，将常规的认知技能和知识习得（被人工智能取代的知识类型）置于深入理解和真实应用之上。事实上，目前开发的人工智能已经可以用于扩展现有的考试实践。例如，人工智能驱动的人脸识别、语音识别、键盘动态和文本取证正越来越多地用于验证远程学习者考生。[64] 尽管这可能对一些学生有好处（例如那些参加面对面考试有困难的残疾学生），但尚未证实这些工具的规模化效果，它们延续了而不是缓解了基于考试的评估实践问题。

另有一种评估方法，或许可以借助人工智能工具不断监测学生的进步情况，提供有针对性的反馈并评估学生的掌握情况。在学生正式接受教育课程期间，可能会对所有这些信息进行整理。虽然使用人工智能驱动的持续评估来取代高风险的阶段性考试可能很有吸引力，但也说明了在教育领域应用人工智能的两个方面：好处和挑战。让学生在学习过程中展示其能力，在某些方面是有利的，但目前仍不太清楚如何在没有持续监察的情况下实现这一点。这种监测涉及许多伦理问题。

人工智能驱动的终身学习成绩记录

“人工智能驱动的电子学习档案”可以用于整理学生在接受正规教育期间的所有持续评估信息，以及学生参与非正规学习（如学习乐器或手工艺）和非正式学习（如习得一种语言）的数据。该记录将作为一种智能和动态简历，可以使用区块链技术来担保和认证。[65] 如此，学生即拥有一个强大的、经认证的学习经历和成绩记录，这有可能比一系列考试证书更详细。学生将能够让高等教育机构和未来雇主安全访问其电子学习档案的相关部分。

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20. 重申终身学习是实现可持续发展目标4的指导方针，其中包括正规、非正规和非正式学习。采用人工智能平台和基于数据的学习分析等关键技术构建可支持人人皆学、处处能学、时时可学的综合型终身学习体系，同时尊重学习者的能动性。开发人工智能在促进灵活的终身学习途径以及学习结果累积、承认、认证和转移方面的潜力。

21. 意识到需要在政策层面对老年人尤其是老年妇女的需求给予适当关注，并使他们具备人工智能时代生活所需的价值观和技能，以便为数字化生活消除障碍。规划并实施有充足经费支持的项目，使较年长的劳动者具备技能和选择，能够随自己所愿保持在经济上的从业身份并融入社会。

（联合国教科文组织，2019a，第7页）

3.3 如何确保人工智能在教育中应用的伦理规范、包容性和公平性?

以合乎伦理、包容和公平的方式将人工智能用于教育领域，影响着每一个可持续发展目标。相关议题集中于以下方面：数据和算法、教学方式选择、包容性和数字鸿沟，儿童的隐私、自由和无障碍发展权，以及性别、残疾、社会和经济地位、种族和文化背景以及地理位置。

关于教育数据和算法的新伦理和法律问题

人工智能技术的广泛部署带来了诸多风险和挑战，包括数据所有权（例如利用数据获取商业利益）、知情同意（例如学生是否有能力在成长或法律层面给予真正的知情同意）和隐私（例如使用侵入性的情绪检测系统）等方面的风险和挑战。另一个风险是，算法的偏见可能会破坏基本人权。还有一个令人担忧的问题是，人工智能数据和专业知识正被少数国际技术和军事超级大国所积累。尽管如此，人工智能技术在教育领域的应用范围非常广泛，且在不断扩大，

> **关于人工智能在教育领域的应用所带来的具体伦理问题，世界各地几乎没有开展任何研究、没有商定任何准则、没有制定任何政策、也没有颁布任何法规来解决这些问题。（Holmes等人，2018b，第552页）**

与主流人工智能一样，人们对为支持人工智能在教育领域的应用而收集的大量个人数据表示担忧——这一过程被称为“数据监控（dataveillance）”（Lupton和Williamson，2017）。谁拥有以及谁能够访问这些数据，存在哪些隐私和保密问题，以及应该如何分析、解读和分享这些数据？所有学习者的个人数据都易遭到滥用或泄露，特别是考虑到全世界仅有不到30%的国家（不包括欧洲）制定了全面的数据保护法律。

另一个重大问题是，人工智能算法（即如何分析数据）中可能包含有意识或无意识的偏见。

事实上，算法在社会中发挥着越来越广泛的作用，从影响某人是否得到工作岗位的决定到某人应接受多久监禁等，各种任务的执行实现自动化。然而，人们越来越认识到，算法并不像其通常展现的那样中立；例如，它们可以自动产生偏见，对个人产生不同程度的负面影响（Hume，2017）。

任何有偏见的分析都可能对学生个人的人权产生负面影响（在学生的性别、年龄、种族、社会经济地位、收入不平等等方面）。然而，这些围绕数据和偏见的特殊伦理问题都是“已知的未知数”，也是主流人工智能领域大量讨论的问题。[66]但有迹象表明，领先的技术公司对“伦理洗白”越来越感兴趣，以试图逃避国家或国际的监管（Hao，2019）。我们还必须考虑“未知的未知数”，即人工智能与教育的互动所引发的那些尚未确定的伦理问题。伦理问题包括：

- 在定义和不断更新收集和使用学习者数据的伦理边界时，应考虑哪些标准？
- 学校、学生和教师如何选择退出大数据的集中呈现，或对此等呈现提出质疑？
- 无法轻易查询人工智能是如何做出决定的（使用多级神经网络），会有什么伦理影响？
- 私营组织（产品开发商）和公共机构（参与研究的中小学校和高校）的伦理责任是什么？
- 学生兴趣和情绪的瞬时性学习过程的复杂性，对数据的解读以及人工智能应用于教育领域的伦理问题有何影响？
- 什么样的教学法在伦理层面是合理的？

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确保教育数据和算法使用合乎伦理、透明且可审核：

28. 认识到人工智能应用程序可能带有不同类型的偏见，这些偏见是训练人工智能技术所使用和输入的数据自身所携带的以及流程和算法的构建和使用方式中所固有的。认识到在数据开放获取和数据隐私保护之间的两难困境。注意到与数据所有权、数据隐私和服务于公共利益的 数据可用性相关的法律问题和伦理风险。注意到采纳合乎伦理、注重隐私和通过设计确保安全等原则的重要性。

29. 测试并采用新兴人工智能技术和工具，确保教师和学习者的数据隐私保护和数据安全。支持对人工智能领域深层次伦理问题进行稳妥、长期的研究，确保善用人工智能，防止其有害应用。制定全面的数据保 护法规以及监管框架，保证对学习者的数据进行合乎伦理、非歧视、公平、透明和可审核的使用和重用。

30. 调整现有的监管框架或采用新的监管框架，以确保负责任地开发和使用用于教育和学习的人工智能工具。推动关于人工智能伦理、数据隐私和安全相关问题，以及人工智能对人权和性别平等负面影响等问题的研究。

（联合国教科文组织，2019a，第8-9页）

此外，人工智能在教育领域的应用因具有侵入性和去人性化（de-humanising）的特征而受到批评：侵入性是因为一些应用需要持续监测学生的行为、姿态和情绪；去人性化是因为一些人工智能要求学生适应指定的教学方法，减少人与人之间的互动，遵循分散内容的结构化路径，这种方式也降低了学习者的能动性。一些案例揭露了伦理方面的争议，比如录制课程并使用人工智能来分析课堂谈话的质量如何有助于学习（Kelly等人，2018）。如果设备不是以侵入性的方式引入课堂，使用人工智能来识别学习模式和问题，也许在伦理层面不会有太大问题。然而，一些学校使用人工智能驱动的教室摄像头监控学生的行为（Loizos，2017）。这已经越过了伦理底线，因为学校安装了面部识别技术来检查学生在课堂上的专心程度。学生的每一个动作都会被安置在黑板上方的多个摄像头所监视。该系统的工作原理是识别面部表情，并将这些信息输入计算机，以评估学生是否精力集中，或在走神儿。其中有一个例子，计算机可以识别七种不同的情绪：平和、快乐、悲伤、失望、愤怒、害怕和惊讶。如果断定学生分心了，就会向老师发出通知，让其采取行动。然而，这些摄像头提高了学生的焦虑水平，改变了他们的自然行为。学生们称，他们觉得有一双神秘的眼睛一直在盯着他们。

另一种由人工智能驱动的方法更甚，它使用头带设备中的脑电图（EEG）[67]传感器来检测学生在执行任务时的大脑活动。开发人员再次声称，这项技术有可能改善学习——这种说法受到了神经科学家的质疑。这些头带设备可能会产生不准确的结果或意想不到的后果。值得注意的是，2019年10月，中国国家互联网信息办公室和教育部出台了相关法规，旨在遏制学校使用人工智能驱动的摄像头、头带和其他设备（Feng，2019）。这些法规要求在对学生使用人工智能技术之前，必须获得家长的同意。另外还规定对所有数据进行加密。目前这已促使中国学校停止使用面部识别和脑电图技术，尽管这可能只是暂时的。

在《北京共识》中，第28至30段阐述了人工智能在教育中的伦理问题。《北京共识》还建议，所有政府均应制定并实施监管框架，以确保负责任地开发和使用人工智能工具进行教育和学习。该项工作应以联合国教科文组织目前正在制定的《人工智能伦理问题建议书》（2020）为基础。

那些掌握和未能掌握核心数字技术（如互联网和人工智能）的人之间的鸿沟问题影响着每个可持续发展目标。更为复杂的是，这种数字鸿沟存在于许多方面，例如：发达国家和发展中国家之间，国家内部不同的社会经济群体之间，技术的所有者和使用者之间，以及依靠人工智能提高工作的人和那些工作容易被取代的人之间。

简单举一个例子，在使用电信网络方面的悬殊差异影响着发展中国家的人们以及发达国家农村地区的人们。此外，尽管近年来宽带价格大幅下降，但数字服务和设备对许多人来说仍然难以负担，这阻碍了人工智能的广泛引入。事实上缺乏宽带设备会导致恶性循环：没有宽带，对数字技术的使用就会受到限制，而那些无法使用数字技术的人就不会出现在机器学习所依赖的数据集之中。这样一来，处于数字鸿沟劣势一侧的人的希望、利益和价值观在人工智能时代被排挤，而新的人工智能也无意中对他们产生了偏见。

由于权力和盈利日益集中于少数国际技术超级大国、仅仅跨越少数几个国家，数字鸿沟进一步加剧。如果没有有效的政策干预，教育领域的人工智能部署可能会反映出这一不可阻挡的进程，难免会放大而非减轻现有的学习不平等。

人工智能推进教育包容性和公平性的契机

除了关注所有人在人工智能技术使用机会方面的公平性之外，我们还需要考虑人工智能在助力实现可持续发展目标4方面的潜力，以帮助**确保包容和公平的优质教育，让全民终身享有学习机会**。为了在2030年实现中小学教育的普及，全球需要再招聘6880万名教师（联合国教科文组织，2016）。在这种具有挑战性的背景下，可能会使用或进一步开发许多人工智能技术，以帮助改善教育——特别是对年长者、难民、边缘化或孤立群体，以及有特殊教育需求的人。[68]然而，我们必须认识到，增加教育机会仍然主要是一个政治和社会问题。人工智能技术可能会有所帮助，但不太可能提供解决方案。例如，起到代替教师功能而非增强教师能力的人工智能技术，可能有助于在教师稀缺的情况下实现短期补救，但可能会无意中加剧而不是解决实现可持续发展目标4的长期挑战。

因此，对于目前人工智能在改善教育和学习方面被夸大的潜力，政策制定者有责任确保慎重看待。首先，应使用联合国教科文组织的ROAM框架（“权利、开放、可及和多方”），确保人工智能在教育中的应用全面解决更广泛的人权和新出现的伦理问题（联合国教科文组织，2019b）。例如，教育领域的人工智能应面向所有公民（不分性别、残疾、社会或经济地位、种族或文化背景或地理位置），特别是对弱势群体（如难民或有学习障碍的学生），不得加剧现有的不平等现象。

《北京共识——人工智能与教育》

2. 重申确保教育领域的包容与公平以及通过教育实现包容与公平，并为所有人提供终身学习机会，是实现可持续发展目标4—2030年教育的基石。重申教育人工智能方面的技术突破应被视为改善最弱势群体受教育机会的一个契机。

23. 确保人工智能促进全民优质教育和学习机会，无论性别、残疾状况、社会和经济条件、民族或文化背景以及地理位置如何。教育人工智能的开发和使用不应加深数字鸿沟，也不能对任何少数群体或弱势群体表现出偏见。

24. 确保教学和学习中的人工智能工具能够有效包容有学习障碍或残疾的学生，以及使用非母语学习的学生。

33. 基于各国自愿提交的数据，监测并评估各国之间人工智能鸿沟和人工智能发展不平衡现象，并且注意到能够获取使用和开发人工智能和无法使用人工智能的国家之间两极分化的风险。重申解决这些忧虑的重要性，并特别优先考虑非洲、最不发达国家、小岛屿发展中国家以及受冲突和灾害影响的国家。

34. 在“2030年教育”的全球和地区架构范围内，协调集体行动，通过分享人工智能技术、能力建设方案和资源等途径，促进教育人工智能的公平使用，同时对人权和性别平等给予应有的尊重。

35. 支持对与新兴人工智能发展影响相关的前沿问题进行前瞻性研究，推动探索利用人工智能促进教育创新的有效战略和实践模式，以期构建一个在人工智能与教育问题上持有共同愿景的国际社会。

36. 确保国际合作有机配合各国在教育人工智能开发和使用以及跨部门合作方面的需求，以便加强人工智能专业人员在人工智能技术开发方面的自主性。加强信息共享和有良好前景应用模式的交流，以及各国之间的协调和互补协作。

（联合国教科文组织，2019a，第7和第9页）

人工智能被用于推进教育包容性和公平性的例子有很多。

- 世界数字图书馆[69]，使用谷歌语音助手，让有识字困难的人只用语音命令就能搜索到书籍，然后由语音助手大声朗读书籍，让他们获得知识。

- Dytective，一种人工智能驱动的筛查工具，使用机器学习对阅读障碍进行早期检测。它由西班牙的Change Dyslexia公司开发，还提供了基于游戏的学习环境，用于练习24种关键的识字技能；[70]

- 人工智能驱动的人工语音[71]，供不能说话或有语言障碍的人使用，有时可以匹配人的原始语音。

- 人工智能驱动的自动语音识别和转录，将原始口语转化为流利的带标点的文字，使聋哑学生更容易参加现场讲座；[72]

- 人工智能和增强现实应用，通过将文本翻译成手语来帮助聋哑儿童阅读，如华为开发的StorySign[73]手机应用；

- 人工智能驱动的“智能”机器人，如针对自闭症谱系障碍学习者的语音机器人，[74]提供可预测的机械互动，帮助学习者培养交流和社交发音；

- 远程临场机器人，供无法上学的学生使用（Heikkila，2018）；

- 人工智能驱动的智能导学系统，是教育领域最常见的人工智能工具，其中一些被用来诊断特定的学习困难并制定个性化学习路径（关于智能导学系统的讨论见第16页第3.1节）。

《北京共识》中反映了人工智能在教育领域实现包容、公平使用的复杂性。为引导人工智能实现包容性和公平性，现提出指导性原则和策略。

3.4 人类如何通过教育实现与人工智能共处及合作?

如前所述，计算机更擅长依赖数据、规律识别和统计推理的任务，而人类在需要同理心、自我指导、常识和价值判断的任务方面仍然更胜一筹。换言之，在帮助学生学习如何在越来越受人工智能影响的世界中有效生存时，所需的教学方法不应是关注计算机擅长的东西（如记忆和计算），而更应强调人类的技能（如批判性思维、沟通、协作和创造力）以及在生活、学习和工作中与普遍存在的人工智能工具协作的能力。

如前所述，第四次工业革命正在对现代生活的许多方面产生着影响，特别是劳动力市场。在许多国家，人工智能已经在接手标准化和重复性的工作，彻底改变了效率，取代了很多工作岗位。然而，据一些世界领先的咨询公司称[75]，人工智能也可能创造许多新的就业机会，并产生积极的整体经济效益，尽管他们对于将取代和创造多少工作机会持有不同意见。

无论长期结果如何，就业的本质可能会发生变化（“工作生活是无常和不可预测的”，Barrett，2017），数以百万计的工人将受到重大影响，而且往往是负面影响。许多人将不得不接受再培训；一生中从事多种职业正迅速成为新常态。[76] 同时，会使用和不会使用新技术的人之间的技能差距[77]将继续扩大，导致越来越多的工人被就业市场排斥，中产阶级将出现“空洞化”（Smith和Anderson，2014）。机会与风险并存，因此需要共同努力，确定每个人如何从发展中获益。国际劳工组织最近的报告《为了更加美好的未来而工作：未来的工作全球委员会》（ILO，2019）指出：

> **无数机会正摆在我们面前，可以提高工作生涯质量、扩大选择、缩小性别差距、扭转全球不平等造成的危害等等。但这一切不会自行发生。如不采取果断行动，我们将进入一个不平等和不确定性进一步加剧的世界。**

事实上，如果各国要确保人工智能不加剧现有的不平等，那么每个公民都必须有机会深入了解人工智能——它是什么、如何工作以及如何影响其生活，这一点将越来越重要。这种认知有时被称为“人工智能素养（AI literacy）”。因此，教师将发挥关键作用，教育供给必须转向支持终身学习，以便人们能够建立自己的能动性、就业能力和贡献社会的能力。换句话说，全球的教育和培训方法都需要采取覆盖整个系统的应对措施，以帮助所有公民做好在人工智能时代和谐生活和工作的准备。

将必要的人类价值观和技能纳入主流，需要建立一个覆盖整个系统、甚至整个社会的框架，其中涉及到几个互补层面：

(i) 促进终身学习，使每个人（尤其是年长者）得以深入了解人工智能[78]（特别是人工智能算法如何选择和操纵数据、如何解读数据以及如何产生偏见）及其对个人和广大社会的影响；

(ii) 将基本的人工智能学习纳入K-12年级学校课程[79]（包括计算思维、数据和算法素养、编程和统计，以使青少年能够生成自己的人工智能工具），我们将在后面更详细地讨论这个问题。

《北京共识——人工智能与教育》

6. 我们还认识到人类智能的独特性。忆及《世界人权宣言》中确立的原则，我们重申联合国教科文组织在人工智能使用方面的人文主义取向，以期保护人权并确保所有人具备在生活、学习和工作中进行有效人机合作以及可持续发展所需的相应价值观和技能。

17. 注意到采用人工智能所致的劳动力市场的系统性和长期性变革，包括性别平等方面的动态。更新并开发有效机制和工具，以预测并确认当前和未来人工智能发展所引发的相关技能需求，以便确保课程与不断变化的经济、劳动力市场和社会相适应。将人工智能相关技能纳入中小学学校课程和职业技术教育与培训（TVET）以及高等教育的资历认证体系中，同时考虑到伦理层面以及相互关联的人文学科。

18. 认识到进行有效的人机协作需要具备一系列人工智能素养，同时不能忽视对识字和算术等基本技能的需求。采取体制化的行动，提高社会各个层面所需的本人工智能素养。

19. 制定中长期规划并采取紧急行动，支持高等教育及研究机构开发或加强课程和研究项目，培养本地人工智能高端人才，以期建立一个具备人工智能系统设计、编程和开发的大型本地人工智能专业人才库。

（联合国教科文组织，2019a，第4和第6页）

(iii) 培养新一代人工智能领域的专业人才，以解决日益扩大的技能鸿沟、填补世界各地创造的人工智能工作岗位。

(iv) 推进高等教育及研究机构开发具有突破性的公平人工智能；

(v) 确保日益增加的人工智能劳动力具有多样性和包容性（涉及女性以及通常被排除在外的其他群体）；

(vi) 预测员工和雇主的新需求，并提供在职提升技能（upskilling）或再训技能（re-skilling)的机会（因为人工智能可实现中低技能工作职责的自动化）

关于让人类与人工智能共处及合作的方案，有各种前景可观的实例，包括帮助年幼学习者培养人工智能技能。同时，各种人工智能平台和工具也在应运而生，以支持这些技能：

- 在中国，“算法和计算思维”已被纳入教育部《普通高中信息技术新课程标准》（中华人民共和国教育部，2017），同时《高等学校人工智能创新行动计划》（中华人民共和国教育部，2018）也旨在提升中国高校的人工智能能力。此外，教育部还发布了“人工智能助推教师队伍建设”行动试点计划，旨在提高教师教育的创新性。

- 在美国，宾夕法尼亚州蒙托尔学区（Montour School District）教授幼儿人工智能编程课程，让学生有机会体验如何通过智能设计助力公益。[80]

- 在新加坡，仿人机器人（如Nao[53]和Pepper[54]）应用到了幼儿园课堂中，为儿童介绍编程和其他STEM学科（Graham，2018）。

- 英国和肯尼亚实施青少年人工智能计划[81]，旨在激励新一代人工智能研究人员、企业家和领导者。它结合编程马拉松、加速器、集训营和导师，让年轻人可以接触到具有社会意识的人工智能部署。

- 新加坡SkillsFuture[82]计划专注于数字技能提升和再训。特别是，该计划为人工智能科学家和工程师提供一系列技能以及对人工智能的基本理解，包括如何与人工智能世界和谐共处。

- 芬兰与赫尔辛基应用科学大学联合开发了一款名为Headai的人工智能应用程序。该应用程序对招聘广告和高校课程实施监测和分析，以创建能力地图[83]，对比人工智能技能的供需情况，然后反过来使高校能够迅速调整课程，以满足市场需求。

- 美国AI4K12[84]计划，由美国人工智能协会（AAAI）和计算机科学教师协会（CSTA）联合发起，提供了一套资源，旨在帮助教师向学生教授人工智能知识。

- 联合国教科文组织的“K12人工智能教学（Teaching AI for K12）”门户网站[85]，汇集了世界各地的人工智能教学资源，供任何教师或家庭教育者使用，以帮助其学生学习人工智能。

- 目前已经设计出免费在线课程，供公民了解人工智能的工作原理。这些课程包括：

  – 人工智能的要素（Elements of AI）[86]：由Reaktor和赫尔辛基大学创建的一系列免费在线课程。课程有多种语言版本，旨在鼓励人们学习什么是人工智能，人工智能能做什么、不能做什么，以及如何开始创建人工智能方法。

  – OKAI[87]：一系列在线课程，提供英文和中文版本。该项目旨在揭开人工智能的神秘面纱，将其概念介绍给没有计算机科学背景或相关知识背景有限的受众。它利用基于网络的互动图像和动画来说明人工智能的工作原理。

  – AI-4-All[88]：是美国的一项非营利性项目，致力于提高人工智能教育、研究、开发和政策的多样性与包容性，目的是为人工智能领域的弱势群体创造更多机会。

4. 利用人工智能实现可持续发展目标4所面临的挑战

尽管人工智能具有应用于教育领域的潜力，但是具体到利用人工智能实现可持续发展目标4，仍面临着许多挑战。整个社会还需要克服更多障碍，以释放人工智能的潜力，减轻其弊端，并建立面向未来的教育系统。首先，人工智能对学生、教师和更广泛的社会的影响还有待确定，包括人工智能干预的有效性、人工智能工具中使用的教学法的选择、学生隐私、教师的工作以及我们在大学和中小学应该教授什么等问题。在本章中，我们简要探讨了一些仍需解决的关键问题。

4.1 数据伦理和算法偏见

如上所讨论，数据处于现代人工智能方法的核心，引发了大量基于数据保护、隐私和所有权以及数据分析的挑战性问题。这些伦理问题引起了广泛关注（Jobin等人总结，2019）。类似地，教育数据的伦理问题也是许多研究的重点（例如Ferguson等人，2016），引发了关于知情同意、数据管理和数据观（例如机构与个人）的进一步问题。人工智能在教育领域的任何应用都应妥善地解决这些数据问题，以及关于教育的其他具体问题，如教学法的选择。

此外，人们早已认识到，通过设计，人工智能会放大其初始数据的隐藏特征，并有力地强化其基本假设。特别是，如果算法

> **是由带有人类偏见的数据训练出来的，那么算法自然也会习得偏见，并且可能会进一步放大偏见。尤其如果人们假定算法是公正的，这会是一个极其严重的问题。（Douglas，2017）**

简言之，人工智能本身并没有偏见，而是在其数据存有偏见或以不适当的算法分析数据时，原有的以及可能尚未发现的偏见可能会更加显著并产生更严重的影响。让偏见变得显著的意义在于这样可以敦促对偏见的纠正，但任由偏见产生更大影响则可能会导致不利结果，因此应该谨慎缓解。

4.2 性别平等的人工智能以及借助人工智能促进性别平等

《北京共识——人工智能与教育》

25. 强调数字技能方面的性别差距是人工智能专业人员中女性占比低的原因之一，且进一步加剧了已有的性别不平等现象。
26. 申明我们致力于在教育领域开发不带性别偏见的人工智能应用程序，并确保人工智能开发所使用的数据具有性别敏感性。同时，人工智能应用程序应有利于推动性别平等。
27. 在人工智能工具的开发中促进性别平等，通过提升女童和妇女的人工智能技能增强她们的权能，在人工智能劳动力市场和雇主中推动性别平等。

（联合国教科文组织，2019a，第8页）

如果人工智能能够为社会带来真实福利，则须竭尽全力确保将公平和性别平等作为人工智能的一项基本原则。然而，目前人工智能的多种应用显示存有性别偏见。例如，2018年，科技巨头亚马逊放弃在招聘中使用机器学习，因为它系统性地歧视女性求职者。根源在于原始数据是以公司的历史招聘记录为基础的，总是不明就里地对女性产生偏见。人工智能在进行自动化选择时，不可避免地放大原始偏见，使其格外显著。一些人提出，亚马逊不应放弃在招聘中使用人工智能，而是应该努力解决这种偏见。另一个例子是关于人工智能个人助手的开发，如苹果的Siri[20]、亚马逊的Alexa[21]、以及百度的DuerOS[22]。许多工具使用的都是女性名字和声音，从而造成了微妙但却非常严重的暗示：

凭借其女性名字、声音和程序化调情特征，虚拟个人助手的设计再现了对女性秘书的歧视性刻板印象——在性别刻板印象中，女性秘书通常不仅是男性老板的秘书。它还强化了女性附属于并顺从男性的角色。这些人工智能助手根据用户的命令运转。它们没有权限拒绝这些命令，且被设定为只能服从。可以说，人工智能助手也提高了人们对于真实女性应该如何表现的期望。（Adams，2019）

在课堂上使用这些具有性别刻板印象的技术可能会产生什么影响，仍是一个有待解决的问题。

解决这些性别平等问题是一个重要的目标，因为只有当女性在人工智能劳动力中有足够的代表性时才有可能实现性别平等，而这本身就是一个令人忧虑的话题。领英（LinkedIn）最近的一项分析显示，在全球人工智能专业人士中，女性仅占22%（世界经济论坛，2018）。推进女性在人工智能领域的代表性，对于保护基本人权并帮助防止人工智能驱动的偏见被扩散和放大至关重要。

4.3 监测、评估和研究人工智能在教育领域的应用

虽然人工智能在教育领域中的应用已有50多年的研究历史，但值得注意的是，人工智能在大学和中小学中仍然比较少见——即使是在发达国家也是如此。事实上，目前甚至尚不清楚正在向教育领域投入的技术是否真的能胜任这项工作。

目前存在的许多“实证性”依据大多是关于人工智能如何以技术能力在教育中发挥作用，而没有询问或详尽回答教育领域是否需要人工智能的问题。（Nemorin，2021）

尽管与传统的课堂教学相比，一些智能导学系统已被证明普遍有效，但关于人工智能在教育领域的应用，几乎没有累积或可复制的研究实例，也缺乏有力的证据证明其规模效应（du Boulay，2016）。事实上，许多人工智能工具的所谓功效可能更多的是在于其新颖性而不是实质内容。我们确实没有足够的证据（Holmes等人，2018a）。

虽然似乎毫无疑问人工智能将对教育机会、内容和结果的输出及管理产生重大影响，但我们仍然不确定人工智能解决方案如何改善这些结果，以及是否能够帮助科学家更好地了解学习是如何发生的。

尤其是许多人提出，人工智能在解决教育问题上可以发挥重要作用，如新冠肺炎疫情期间学校关闭所造成的不断增加的不平等现象。在疫情的最初几个月，许多教育领域的人工智能商业公司报告称注册用户激增。然而，几乎没有证据表明，这些系统的起到的作用大于虚拟儿童监护的功能，或者青少年因使用这些系统而收获更多。因此，在政策制定者认为人工智能可以解决疫情造成的教育问题之前，需要进一步研究和评估，以区分现实和夸大其词。最终，人工智能也许能够发挥有益的作用，但目前我们根本没有足够的信息来了解它的助益程度。

《北京共识——人工智能与教育》

15. 支持采用全校模式围绕利用人工智能促进教学和学习创新开展试点测试，从成功案例中汲取经验并推广有证据支持的实践模式。

31. 注意到缺乏有关人工智能应用于教育所产生影响的系统性研究。支持就人工智能对学习实践、学习成果以及对新学习形式的出现和验证产生的影响开展研究、创新和分析。采取跨学科办法研究教育领域的人工智能应用。鼓励跨国比较研究及合作。

32. 考虑开发监测和评估机制，衡量人工智能对教育、教学和学习产生的影响，以便为决策提供可靠和坚实的证据基础。

（联合国教科文组织，2019a，第6和第9页）

4.4 人工智能将对教师角色产生哪些影响?

《北京共识——人工智能与教育》

12. 注意到虽然人工智能为支持教师履行教育和教学职责提供了机会，但教师和学生之间的人际互动和协作应确保作为教育的核心。意识到教师无法被机器取代，应确保他们的权利和工作条件受到保护。

13. 在教师政策框架内动态地审视并界定教师的角色及其所需能力，强化教师培训机构并制定适当的能力建设方案，支持教师为在富含人工智能的教育环境中有效工作做好准备。

（联合国教科文组织，2019a，第5页）

尽管使用智能导学系统的商业目标是完成教师职责，但在短时间内机器仍不太可能取代教师。尽管如此，许多人工智能开发人员的志向是减轻教师的各种负担（如监测进度和批改作业），使教师可以专注于教学的人性化方面（如社会参与、移情互动，并提供个人指导）。然而，随着人工智能功能的改进，其必然会减轻教师越来越重的负担。相应地，鉴于人工智能工具接手知识传输任务、促进学生的低阶思维，教师的作用也会随之降低。从理论上讲，教师因此可以更专注于设计和推进需要高阶思维、创造力、人际协作和社会价值的学习活动——尽管人工智能开发人员无疑已经在努力实现这些任务自动化。因此，为了确保教师继续在青少年教育中发挥关键作用，政策制定者必须从战略上审查人工智能如何改变教师的角色，以及教师如何准备在人工智能教育环境中工作。

4.5 人工智能将对学习者能动性产生哪些影响?

即使避免了以人工智能取代教师的反乌托邦式场景，学习者的能动性仍可能会因教育领域过多地使用适应性人工智能而减弱。这意味着学习者相互交流的时间减少，更多的决定由机器做出，并且更关注最易于自动化的知识类型。这可能会剥夺学习者培养其智谋（resourcefulness）、自我效能、自我管理、元认知、批判性思维、独立思考和其他21世纪技能的机会，而这些技能却是全人培养的关键（世界经济论坛和波士顿咨询集团，2016）。目前还不清楚这将对学生、公民和教育规划产生什么长期影响。

由Facebook工程师开发的一种智能导学系统“巅峰学习（Summit Learning）”，目前大约有400所学校正在使用，而它已经成为学生抗议和抵制的焦点。多所学校的学生走出校门抗议，称他们使用该程序的体验并不好——它要求上课期间学生在电脑面前坐数个小时。他们特别担忧的是，该程序剔除了发展批判性思维所需的许多人际互动和教师支持（Robinson和Hernandez，2018）。资助“巅峰学习（Summit Learning）”项目的陈-扎克伯格计划（Chan Zuckerberg Initiative）对这些说法提出了异议。

此外，如前所述，人工智能会放大其初始数据的隐藏特征，并有力地强化其基本假设。在这方面，基于规则和机器学习的人工智能技术是相似的（Holmes等人，2019）。这些技术的设计和大多指令式的实施方法，以知识转移和内容传递为重点，忽视了背景和社会因素，放大了关于教学方法已有但存在争议的假设。这一系列的关键问题，需要人工智能教育界的充分参与。人工智能在教育领域的所有应用都应该加强而不是威胁全人的培养。

5. 政策应对综述

正如经济合作及发展组织（OECD）所指出的，全球60个国家以及欧盟地区实施了300多项人工智能政策计划。[89] 其中大部分都提到了教育问题。例如，许多计划中提到人工智能能力建设的需要（即“学习人工智能”），但大多数局限于高等教育。有些还提到了再培训，这对减轻人工智能对工人的影响越来越有必要。

然而，尽管设定了可持续发展目标4，但是很少有计划关注K12阶段的人工智能学习，如何在教育中实施人工智能（即“使用人工智能学习”），或让公民做好准备，以适应越来越受人工智能影响的世界（即“为了人机协同而学习”）。

在本章中，我们总结了一些专门针对人工智能与教育的国家和地区政策，为其他国家的决策者根据现有通用人工智能计划制定策略时提供参考。

5.1 政策应对方式

应对人工智能与教育发展问题的跨国和区域性政策多种多样，但大致可以分为三种方式：独立式、综合式或专题式（见表3）。

■ 独立式
拥有独立的人工智能政策和战略，如欧盟的《人工智能对学习、教学和教育的影响》（Tuomi，2018），以及中国（2017）的《新一代人工智能发展规划》。

■ 综合式
将人工智能要素融入到现有的教育或信息通信技术政策和战略中，如阿根廷的“Aprender Conectados（学习互联）”（阿根廷教育部，2017）。

■ 专题式
专注于与人工智能和教育有关的某一特定主题，如欧盟的《通用数据保护条例》（GDPR）。

接下来我们将对这三种方法逐一进行详细探讨。

独立式

■ 2016年，美国发布《国家人工智能研究与发展战略计划》。在人工智能在教育中的应用方面，该计划强调改善教育机会和生活质量。具体而言，它认为：(i)借助人工智能赋能的学习技术，可以普及自适应自动辅导；(ii)人工智能教师可以作为人类教师的补充，帮助提供适合个人的进阶性和辅导性学习；以及(iii)人工智能工具可以促进所有社会成员进行终身学习并习得新技能。

■ 2016年，韩国发布《智能信息社会中长期准备计划》，该计划包括从2020年开始每年培训5,000名人工智能应届毕业生，到2030年为其人才库新增50,000名人工智能专家。

■ 2017年，中国发布《新一代人工智能发展规划》，主张发展“智能教育”。具体而言，该计划涉及到利用人工智能来：(i)发展新的教育系统，包括改革教育实践、提供智能和互动学习；(ii)开展智能校园建设，促进人工智能在教学、管理和资源建设中的应用；(iii)发展三维综合教学方法和基于大数据的智能在线学习平台；(iv)开发人工智能助手，建立综合教育分析系统；以及(v)建立以学习者为中心的教育环境，为每个学习者提供个性化教育。

■ 2017年，阿拉伯联合酋长国（UAE）启动“阿联酋人工智能战略”。该计划涵盖了人工智能在九大主要部门的开发和应用，其中一个部门就是教育。其还强调了人工智能在降低成本和加强学习方面的潜力。

■ 2018年，欧盟发布了《人工智能对学习、教学和教育的影响》。这份文件首先阐述了人工智能对学习的影响，特别是对儿童和成人的人类认知能力的影响。它认为，人工智能可以支持现有的认知技能，加快认知发展，创造新的能力，并可能降低一些能力的重要性或导致这些能力被淘汰。其次，该文件还阐述了人工智能面向未来愿景的需求，以及人工智能对未来学习的影响，特别是对人工智能生成的学生模型和新的教学机会的影响。此外，这份文件强调，人工智能可能会在系统层面上产生深刻的影响。它承认，在正在进行的广泛变革，即第四次工业革命中，人工智能仅仅是一个方面。为了应对这种情况，作者认为，必须重新思考教育在社会中的作用、如何组织教育，以及教育应该解决哪些目标和需求。

■ 2019年，马耳他启动“迈向人工智能战略”。该项目以三大战略支柱为基础：(i)投资、创业和创新；(ii)公共部门采用人工智能；以及(iii)私营部门采用人工智能，并以教育作为关键赋能领域。其中规定，国家教育体系必须

表3：教育领域中人工智能相关政策指引概述

	方法		
	独立式	综合式	专题式
阿根廷		“学习互联”（Aprender Conectados）（阿根廷教育部，2017）	
中国	《新一代人工智能发展规划》（中华人民共和国政府，2017）。		《普通高中信息技术新课程标准》（中华人民共和国教育部，2017） 《高等学校人工智能创新行动计划》（中华人民共和国教育部，2018）
爱沙尼亚			“编程老虎”项目（ProgeTiger）（HITSA，2017）
欧盟	《人工智能对学习、教学和教育的影响》（Tuomi，2018）		《通用数据保护条例》（GDPR）（欧盟，2016、2018） 《欧洲公民数字能力框架》（DigComp）（Carretero等人，2017）
马来西亚		#我的数字创作器（#mydigitalmaker）（教育部和马来西亚数字经济公司，2017）	
马耳他	《迈向人工智能战略——高级政策文件征求意见稿》（马耳他政府，2019）		
韩国	《智能信息社会中长期准备计划》（韩国政府，2016）		
新加坡			Code@SG倡议——发展全民计算思维（资讯通信媒体发展局，2017）
阿拉伯联合酋长国	《阿联酋人工智能战略》（阿拉伯联合酋长国，2017）		
美国	《国家人工智能研究与发展战略计划》（国家科技委员会，2016）		

不断变革以适应第四次工业革命的要求。如今有很大比例的儿童在会说话之前就学会了与电子设备进行熟练互动，并浏览移动操作系统。他们在成长过程中把技术视为生活中不可或缺的一部分。事实上，他们很少对“连接中断”这样的想法感到感伤，因为在他们所见的世界中，移动设备上始终联网且持续推送着个性化的内容。数字工具在马耳他的大多数学校都很普遍，学校教师会使用交互式白板和平板电脑来增强教育体验。然而……马耳他（还）必须考虑如何拓展课程本身，使儿童更好地做好准备，以适应由人工智能协助、支持和强化决策过程的未来工作场所。（马耳他政府，2019）

综合式

■ 2016年，马来西亚启动“#我的数字创作器”（#mydigitalmaker）倡议，将计算思维融入教学课程。该项目倡导私营部门、公共部门和学术界相互协作，以“帮助创建并鼓励设置与教育部设定的目标相匹配的数字制作课程”（教育部和马来西亚数字经济公司，2017）（Pedro等人，2019）。

■ 2017年，阿根廷发起“学习互联（Aprender Conectados）”项目，旨在将数字学习融入各级义务教育。阿根廷计划到2019年前，实现编程和机器人技术在所有学校的推广和普及。该课程规定为学龄前儿童到中学生的各个年龄层次提供有针对性的学习能力方案，充分发展其通过单独和协作使用计算方法和技术解决问题的综合能力。

专题式

■ 2016年，欧盟议会批准了《通用数据保护条例》（GDPR），并于2018年生效。制定该条例的目的在于：(i)协调欧洲各地的数据隐私法；(ii) 保护所有欧盟公民的数据隐私；以及(iii) 重建欧洲各组织机构处理数据隐私的方式。

■ 2017年，欧盟推出了《欧洲公民数字能力框架》（“DigComp”）（Carretero等人，2017），其中将数字能力解释为包括下列内容：(i)信息和数据素养；(ii)交流与协作；(iii)数字内容创造；(iv)安全性；(v)解决问题能力。

■ 2017年，中国推出《普通高中信息技术新课程标准》（中华人民共和国教育部，2017）。本文件提高学生的(i)信息意识；(ii)计算思维；(iii)数字学习和创新能力；以及(iv)信息社会的责任。

根据《普通高中信息技术新课程标准》的规定，信息通信技术课程包括信息通信技术必修课程、选修课程一和选修课程二。信息通信技术必修课程包括两个模块：(i)数据与计算；(ii)信息系统和社会。选修课程一由基本模块和应用模块组成。其中，基本模块包括：(i) 数据和数据结构，(ii) 网络基础知识；和(iii)数据管理和分析。应用模块包括：(i)应用程序设计；(ii)三维设计和创造性；(iii)开放硬件项目设计。选修课程二涉及算法基础知识和智能系统介绍。

■ 2018年，中国启动《高等学校人工智能创新行动计划》（中华人民共和国教育部，2018），旨在推动高校人工智能的发展，其中包括：(i)优化高校人工智能领域的创新体系；(ii)完善人工智能人才培养体系；以及(iii)强化高校科技成果在人工智能领域的应用。

■ 2017年，新加坡推出“Code@SG倡议——发展全民计算思维”（新加坡资讯通信媒体发展局，2017）。该倡议强调从学生幼年起即需要促进编程和计算思维，因为编程和计算思维在人们的日常生活和工作中发挥着越来越重要的作用。

■ 2012年，爱沙尼亚启动了由教育信息技术基金会（Hariduse Infotehnoloogia Sihtasutuse，HITSA）管理的“编程老虎”项目（ProgeTiger），由爱沙尼亚教育和研究部资助。该计划将编程和机器人技术纳入学前、小学和职业教育的全国课程当中。

5.2 共同政策关注领域

从上述国家和区域政策来看，出现了四个主要关注领域：

■ 管理数据和隐私的重要性（例如欧盟《通用数据保护条例》的规定）；

■ 无论是对于人工智能技术还是数据，重视开放性的核心价值——有助于确保平等、普遍提供机会，弥合信息的不平等，促进增强透明度（联合国教科文组织，2019b）；

■ 可以解决人工智能的潜在问题和影响的课程创新，以马耳他的《迈向人工智能战略—高级政策文件征求意见稿》（马耳他政府，2018）为例，其中声明“马耳他的教育体系还需要发展并适应第四次工业革命的要求”；

■ 为有效实施人工智能提供经济支持，如韩国为人工智能专业学生设立4,500个国内奖学金，同时承诺拨款约20亿美元设立6所人工智能研究生机构，投入400万美元用于人工智能研究。

5.3 筹资、伙伴关系和国际合作

为了最大程度地实现人工智能在教育领域发展的效益，同时降低风险，必须做好全系统规划，开展关键评估，采取集体行动，持续投入资金、执行有效且有针对性的研究，加强国际合作。然而，在现实情况中，已经做好此类规划准备的国家或利益相关方则是凤毛麟角。真正积极参与技术对接、调动资源、确保人工智能在大规模学术研究的基础上得到应用的国家或利益相关方基本是屈指可数。大多数人还未认识到人工智能可能需要对学习方式进行根本性的改革，更不用说会积极探索改革和创新。相反，讨论仍然停留在较为肤浅的层面。比如说，许多人认为学习的“个性化”是好事，但其定义较为含混；究竟是指为学习标准化内容制定个性化路线，还是指个性化的结果、能动性和自我实现？简单来说，仅仅认为人工智能应当用于教育环境显然是不够的。相反，利益相关者还必须考虑应当使用哪些人工智能技术，如何对其加以利用，以及它们真正能够实现什么样的目标。

《北京共识——人工智能与教育》

37. 通过联合国教科文组织移动学习周等方式并借助其他联合国机构，为各国之间交流有关教育人工智能领域的监管框架、规范文本和监管方式提供适当的平台，从而支持在发掘人工智能潜力促进可持续发展目标4方面开展南南合作和北南南合作，并从中受益。

38. 建立多利益攸关方伙伴关系并筹集资源，以便缩小人工智能鸿沟，增加对教育人工智能领域的投资。

（联合国教科文组织，2019a，第10页）

6. 政策建议

6.1 全系统愿景和战略优先事项

确定人工智能与教育政策的全系统愿景

在教育领域应用人工智能，主要目的应该是促进学习，使每名学习者都能开发个人潜力。这些政策均应予以如实反映和支持。然而，各国如果想要克服在实现可持续发展目标4的过程中遇到的挑战，就需要调整政策，使之不仅仅局限于人工智能在教育领域的应用，将人工智能与教育的所有关联考虑在内。这就意味着要使人们了解人工智能如何运作，人工智能创造的过程，以及人工智能对当地和全球社会的广泛影响。

人工智能与教育政策的四大战略目标，须因地制宜地予以解释（即对于许多中低收入国家，关注点可能主要侧重于确定人工智能准备情况的差距并着手解决，如基础设施和资金方面的差距）：

- 确保人工智能在教育领域中应用的包容性和公平性；
- 利用人工智能加强教育和学习；
- 推动发展人工智能时代的生活技能，包括教授人工智能的运作方式及其对人类的影响；
- 保障教育数据使用的透明化，且可对其使用过程进行审查。

然而，人工智能并非灵丹妙药，还有许多需要商议的事情，也有不少挑战亟待解决。

以下指导原则和政策建议还借鉴了《北京共识》（联合国教科文组织，2019a），该共识在北京举行的国际人工智能与教育会议（2019年5月16日至18日）上达成。

据此，在阐明人工智能与教育政策的指导原则后，我们提出以下建议：

- 跨学科**规划**和跨部门**治理**；
- 确保公平、包容和合乎伦理地应用人工智能的**政策**；
- 为教育管理、教学、学习和评估人工智能的使用制定**总体规划**；
- 试点测试、**监测和评估**，并建立实证库；
- 促进本土化教育**人工智能技术创新**。

评估全系统的准备情况，选择战略优先事项

- **考虑教育政策规划战略优先事项之间的权衡关系，包括人工智能应用和其他优先事项之间的权衡关系，以及政策不同重点领域或构成部门之间的权衡关系：**这种权衡关系的基础是认真审视人工智能技术在本土情况下有助于实现可持续发展目标的潜力，并辅之以投资要求，即在教育环境中实施以人工智能应用为中心的政策和方案。此后，分析现有和新兴人工智能技术是否适合解决相关挑战，实现可持续发展目标4及其目标，以此确定战略优先事项。根据当地各个部门中发展人工智能技能和价值观的紧迫性，考虑其他可持续发展目标。应用或创建成本价值评估模式，评估实施人工智能政策和方案的教育效益（如提高效用、提高效率、扩大可及性）是否大于成本（如基础设施翻新、培训、整合以及信任降低和自主权的风险、内容质量低下、滥用教育数据等）。

→ 示例

全球人工智能战略态势——探索50个国家人工智能战略打造人类未来的潜力：https://www.holoniq.com/notes/the-global-ai-strategy-landscape/；

解读中国的人工智能梦想——中国领导人工智能世界战略的背景、构成、能力和后果（Ding，2018）：https://www.fhi.ox.ac.uk/wp-content/uploads/Deciphering_Chinas_AI-Dream.pdf

- **基于全系统准备情况以及成本价值评估，确定政策的战略目标：**应用或开发相关工具，评估全系统人工智能准备情况，包括基础设施；互联网连通性；数据、人工智能工具和本土人工智能人才的可用性；关键政策执行者的技能；以及利益相关者的认知情况。在确定时限性目标时，尽管本土人员配置水平、基础设施和流程方面存在系统性不足，但仍应确保实现人工智能系统的现实预期效益。教育范式的概念性未知和局限可能影响人工智能系统的能力，对此应将其纳入考虑。缓解系统研究欠缺对人工智能在教育中应用的影响。

→ 示例

全球人工智能准备指数：https://bit.ly/2UR2HXp

6.2 人工智能与教育政策的指导原则

采用人本主义方法作为人工智能与教育政策的指导原则

■ **指导人工智能与教育政策的制定和实践，以期保护人权，确保公众具备可持续发展所需的价值观和技能，并在生活、学习和工作中进行有效的人机协同**；确保人工智能由人控制，以服务公众为中心，旨在提高学生和教师的能力。以伦理、非歧视、公平、透明和可审查的方式设计人工智能应用；并监测和评估人工智能在整个价值链条中对人和社会的影响。

■ **培养人类价值观，开发和应用人工智能。**在人工智能技术提高生产力的背景下，分析市场回报与人类价值观、技能和社会福利之间的潜在紧张关系。确定将人与环境置于效率之前的价值观，同时优先考虑人际互动，而非人机交互。

广泛树立企业和公民责任，以解决人工智能技术提出的关键社会问题（如公平性、透明度、问责制、人权、民主价值观、偏见和隐私）。确保将人始终置于教育的核心，将其作为技术设计的隐含部分；在尚未确定和补偿当前实践价值的情况下防止其自动执行任务。

→ 示例

人文主义人工智能项目——法国人工智能战略：
https://www.aiforhumanity.fr/en/

欧盟可信赖的人工智能伦理指南：
https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

经济合作及发展组织人工智能原则：
https://www.oecd.org/going-digital/ai/principles

6.3 跨学科规划和跨部门治理

调动跨学科和多方利益相关者的专业知识，为政策规划提供信息，并建设决策者的能力

■ **为决策者和教育管理者提供知识并树立信心，从而了解人工智能日益丰富的教育生态系统并做出决策：为决策者（包括财务规划师、政策制定者和政策实施管理者）提供持续培训机会**；促进国内外利益相关者之间就专业知识和最佳实践展开交流；引导利益相关者充分了解应利用人工智能技术解决的教育难题。

→ 示例

人工智能要素课程： https://www.elementsofai.com

■ **汇集跨部门、跨学科和多方利益相关者的专业知识，为政策规划的关键决策提供信息：**汇集不同研究界人士（如神经科学、认知科学、社会心理学和人文科学的教育工作者、学习领域科学家和人工智能工程师等）的专业知识，设计出以用户为中心且基于结果的人工智能技术，以满足真正的课堂需求；联系各国际组织，为人工智能决策提供信息和建议；考虑人工智能的发展潜力，并结合和分析多种数据源，以改善决策效率。

→ 示例

欧洲人工智能联盟的人工智能高级专家组： https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence

建立跨部门治理和协调机制

■ **采用整个政府和全系统方法，规划和管理教育环境中人工智能应用的政策：**一致的全系统战略以及循证包容性方法（如参与式设计和共同创造框架，Pobiner和Murphy，2018），以确保人工智能与教育和现有教育政策及任何更广泛的国家人工智能战略相一致并融合；针对在整个教育系统或任何更广泛的跨部门战略中的人工智能应用，如果达成共识，则考虑将人工智能在全系统改造中进行推广运用。

■ **为政策治理和协调建立全系统的组织结构，**以确保实施过程能够平衡自上而下和自下而上的方法，这涉及关键合作伙伴和利益相关者尽可能实现跨部门协作和资源共享。其中应包括一个中央管理委员会，负责指挥、支持和监督政策执行；一个协调机构，负责管理合作伙伴和协作；一个代表小组，负责执行政策。最为重要的是，应制定一套关于政策治理的综合原则，并始终如一地贯彻执行，让委员会能够行使所有权和问责制。

→ 示例

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

■ **建立开放和迭代的循环，包括规划、实施、监测和更新政策的关键步骤：此类步骤应形成持续的学习过程；**监测和研究应整合到总体规划中，重点关注技能、知识和价值观的具体成果和收益。监测和研究必须进行战略性沟通，并通知决策者，以便反馈至有效且可靠的实证基础，以促进发展。政策执行过程必须允许审查和修改。

■ **促进开源人工智能的本土化和重复利用，以孵化本土开发：**根据具体的国家和文化背景，打造专门性的开源人工智能工具和平台，这一点较为关键，这是因为很多的人工智能技术都是专有知识产权。采用共享数据和算法的开源代码策略，培育本土创新能力，并缓解国家之间和学习者群体内部的数字鸿沟。

→ 示例

全球南营人工智能目录，“Knowledge 4 All”基金会：https://www.k4all.org/；

X5gon项目（跨模式、跨文化、跨语言、跨领域和跨站点的全球OER网络）：https://www.x5gon.org/；

日本“Society 5.0”：https://www8.cao.go.jp/cstp/english/society5_0/index.html

6.4 确保公平、包容和合乎伦理地应用人工智能的政策和法规

制定跨部门的战略目标，规划规章制度和方案，确保在教育中公平、包容地使用人工智能

■ **建立和监测可衡量的目标，以确保教学和开发人工智能服务的包容性、多样性和公平性：确定哪些人将从其实施活动中受益；**加强适当的基础设施，如互联网接入、硬件和软件，以便公平地利用教育人工智能所带来的效益。采取措施使之社会最脆弱群体接触；专注于具有可靠业绩记录的教育行业人工智能，其中涵盖不同背景和能力的学生。

→ 示例

数字孟加拉国：https://a2i.gov.bd

■ **审查人工智能减轻或加重偏见的能力：**揭示未知的风险，并减轻此类风险；测试人工智能工具，并确认其并不存在偏见（Pennington，2018），且已接受有关多样化（性别、残疾状况、社会和经济地位、种族和文化背景以及地理位置等）数据代表性的培训。培养重视公平、公正人工智能的理念，尊重这种多样性。激发一种设计方法，将伦理、隐私和安全融入到教育领域人工智能的研究和开发中。

■ **创建无性别偏见的人工智能应用程序，确保用于开发的数据具有性别敏感性：**激励促进性别平等的人工智能应用程序；赋予妇女和女孩人工智能技能，以促进劳动力和雇主实现性别平等。

→ 示例

联合国教科文组织的出版物《**如果我能，我会脸红**》（I'd blush if I could），其中就阐述了消除不同性别之间的数字技能差异策略：https://unesdoc.unesco.org/ark:/48223/pf0000367416

■ **制定数据保护法律，确保教育数据的收集和分析过程可见、可追踪，并可由教师、学生和家长进行审查：**为谋求公共利益制定有关数据所有权、隐私权和可用性的明确政策。遵循专家组围绕更广泛的人工智能数据问题而制定的国际准则；并遵守国际公认的伦理规范。

→ 示例

自2018年5月25日起适用于所有欧盟成员国的《**通用数据保护条例**》，以协调整个欧洲的数据隐私法律：https://gdpr-info.eu/；

欧盟可信赖的人工智能伦理指南：https://ec.europa.eu/digital-single-market/en/news/ethics-guidelines-trustworthy-ai

■ **调查在开放获取和数据隐私之间实现平衡的方案：**测试和采用新兴的人工智能技术和工具，以确保教师和学生的数据隐私权和安全性。制定全面的监管框架，以保证学习者以伦理、非歧视、公平、透明和可审查的方式使用和重复使用数据。

■ **促进有关人工智能伦理、数据隐私和安全性问题的公开讨论，以及关于人工智能对人权和性别平等负面影响的关注：**确保人工智能用于积极善意的方面，防止有害应用。解决知情同意的复杂问题——特别是在不少使用者无法真正给予知情同意的情况下（如有学习障碍的儿童和学生）。

→ 示例

DataKind，倡导社会组织应与大型科技公司一样可以获得数据科学资源：https://www.datakind.org

6.5 在教育管理、教学、学习和评估中使用人工智能的总体规划

利用人工智能促进和提升教育管理和供给

■ **探索人工智能技术如何能够改进教育管理信息系统（EMIS）：**利用人工智能使教育管理信息系统更加稳定可靠、便于访问、精简、功能强大、用户友好且高效。使循证决策和管理朝着更加灵活、动态化和民主化的过程发展，数据流的发展更能适应社会和教育模式的变化。投资于可以利用人工智能能力的方案，实现对技能和需求的全系统预测，使政府能够做好满足当地相关教育需求的准备，并将其与金融、经济、法律和医学等部门相结合。

→ 示例

开放大学的**OU分析**，通过分析该大学教育管理信息系统的大数据，预测学生成绩，并找出存在考试不及格风险的学生： https://analyse.kmi.open.ac.uk

■ **实现教育管理信息系统的整体转型及其与学习管理系统（LMS）的整合：**确保教育管理信息系统根据人工智能赋能教育所引发的变化而相应做出调整，提供将学习管理系统与教育管理信息系统集成的手段，从而助力其朝着更综合、更丰富、更全面的评估方式发展。

→ 示例

智学网（智慧学习）是由中国科大讯飞开发的学习管理系统，提供个性化在线辅导课程：https://www.zhixue.com/login.html

■ **授权管理者、教师和学生推广应用以人工智能为动力的教育管理信息系统和学习管理系统：**分析将以人工智能赋能教育管理信息系统和学习管理系统引入学校的成本。确保降低学校管理者和教师的准入成本，为其带来效益，而不会增加行政工作负担。建立并监测可视化、透明的过程，自动收集有关教师实践和学生活动的数据。推广使用人工智能，支持个性化的资源和结果，使学习者可以形成个人见解，并在不同的环境中充分发挥自己的技能和知识，同时保留对其个人数据和数字身份的控制。

→ 示例

LabXchange由安进基金会和哈佛大学文理学院联合推出，是免费的在线科学教育平台，为用户提供个性化教学、虚拟实验室体验，以及与全球科学界建立联系的机会：https://www.multivu.com/players/English/8490258-amgen-foundation-harvard-labxchange

培养以学习者为中心的人工智能应用，以加强学习和评估

■ **在机器和计算机代理知识日益丰富的背景下，强化和重申人类对自身学习的权威和自主性：**询问教师和学生对人工智能技术的看法，并根据反馈意见确定如何在学习环境中部署人工智能。让学生了解收集到的数据类型，如何使用这些数据，以及这些数据可能对学生的学习、职业和社交生活产生的影响。防止机构将人工智能技术用于监控目的——相反，应当树立学生之间的信任，并使用人工智能敦促学生取得进步，而不是增加监视。

■ **在整合人工智能工具的过程中，强调学生的能动性与社会福祉：**保护学生作为个体成长的能动性和动力；保护游戏和休闲时间、社会互动和学校休息时间。使用基于人工智能的工具，尽量减轻家庭作业和考试的压力，而不是徒增压力。支持学生适应新的人工智能工具和方法，以便此等工具和方法能够对其学习产生积极的影响；让学生认真观察在课堂上使用人工智能所带来的挑战，并给予反馈。

→ 示例

科大讯飞研发的智能儿童关爱机器人**阿尔法蛋（AlphaEgg）**：https://ifworlddesignguide.com/entry/203859-alphaegg；

The CoWriter：利用机器人学习提升写字水平，由瑞士洛桑联邦理工学院CHILI（学习和教学中的人机交互）开发：https://www.epfl.ch/labs/chili/index-html/research/cowriter; https://www.youtube.com/watch?v=E_jozVysl5g

■ **审查和调整课程，以反映在教学与学习中日益广泛采用人工智能所带来的教学和评估变化：**与人工智能提供商和教育工作者合作，确定应对课程框架和评估方法变化的最恰当方式，为探索人工智能提供有利的政策环境和课程空间。开展全国倡议，邀请学生代表参与，以提升课程新能力。

→ 示例

数字教育（Digital Education），面向所有阿根廷学生的编程和机器人技术教育：https://www.argentina.gob.ar/educacion/aprender-conectados/nucleos-de-aprendizajes -prioritarios-nap

■ **测试和部署人工智能技术，以支持能力和结果的多维度评估：**将人工智能整合到心理测量评估中，可能包括在情境判断测试中与学生进行聊天机器人式对话。避免将人工智能作为预测学生未来教育和职业发展的唯一手段。针对“基

于规则”的封闭式问题的回答，在采用基于算法的自动评分时，应要谨慎；支持教师使用基于人工智能的形成性评估，将其作为人工智能赋能学习管理系统的集成功能，以更高的精度和效率分析学生学习的数据，并减少人为偏见。挖掘基于人工智能的渐进式评估潜力，为教师、学生和家长提供定期更新。从人性化的角度，测试并评估在远程在线考试中使用人脸识别和其他人工智能技术进行用户认证和监考的效果。

→ 部分示例

基于人工智能的评估系统： https://www.researchgate.net/publication/314088884_Towards_artificial_intelligence-based_assessment_systems

确保人工智能用于赋能教师

保护教师的权利及其实践的价值：与教育工作者协商，确保其权利得到保护，并在部署人工智能技术时考虑他们的意见。开展试点研究和规模试验，集成人工智能技术时，重点关注教师的日常实践需求；促进人工智能工具的研发，用以支持教学工作，而不是取代教师的核心职能。提供循证指导，使教师能够掌握私营部门提供的基于人工智能的技术；制定标准和评级，帮助教师在知情的前提下决定哪些工具最适合其需要。

■ **分析和审查教师在促进知识转移、人际互动、高阶思维和人类价值观方面的作用：**分析自动执行某些任务的益处，避免减少或损害学习实践的风险。对于需要耗费教师大量时间但能提供重要信息的任务，减少自动化执行；确定依靠教师自主性和动力的具体方面；在将人工智能引入教学实践的过程中继续保留和强化这些要素，并保持对教师权威和能力的高度信任。

■ **确定教师所需的技能，以便于其在设计和组织学习活动以及自身专业发展中，搜寻和应用人工智能工具：**分析教学环境中人机协同所需的技能。在将人工智能应用于教师职业发展、管理基于人工智能的评估以及设计和实施人工智能强化学习活动时，应评估所需的模式变更。参考《联合国教科文组织教师信息与通信技术能力框架》（教科文组织，2018），更新教师框架和培训计划。

■ **提供培训，确保持续支持，帮助教师获得有效使用人工智能的技能：**在部署人工智能平台或工具之前，制定并提供规定技能的培训计划；防止出现由于人工智能功能不可用或不可靠而导致教师无法履行其职责的情况。提前计划，确保教师能够将人工智能新技术应用到其当前的实践中，并过渡至新的工作方式；鼓励形成教育者社区，分享经验和日常最佳实践，并促进人工智能工具的创新使用。提供基于新兴技术研究的简化指南，使教师随时掌握可在课堂环境中应用的最新成果，并增加教师终身学习的机会，紧跟课堂内外人工智能所带来的变化。

→ 示例

《联合国教科文组织教师信息与通信技术能力框架》：
https://unesdoc.unesco.org/ark:/48223/pf0000265721；
K-12教育中的人工智能资源，国际教育技术协会（ISTE）：
https://www.iste.org/learn/AI-in- education

计划使用人工智能支持不同年龄、地点和背景的终身学习

■ **积极寻求和推广人工智能的使用，旨在支持广泛的教育方法和多样化的终身学习途径：**培养和维护各机构利用人工智能的能力，使其更具活力，能为更多的非传统学习者提供服务，并提供正式、非正式、日常场合的终身学习。为传统机构提出可行的机制，使其向混合方法的方向发展，将面对面教学与动态发展的人工智能赋能课程相结合；同时为机构和人工智能提供商之间的伙伴关系提供激励，以促进人工智能工具的发展，最大限度地增加终身学习的机会。

■ **建立人工智能工具和系统，跟踪不同学习水平和地点的学习成果和证书：**开发人工智能平台、工具和系统，跟踪学习成果，实现更简单的技能专业化；探索使用人工智能的各种方法，以扩大教育证书和资格认证途径的用途。

→ 部分示例

新加坡政府的**技能未来（SkillsFuture）倡议：** https://www.skillsfuture.gov.sg；新加坡的**开放认证（OpenCert）**，支持验证任何机构颁发的终身学习证书：https://opencerts.io

■ **解决不同年龄群体在获得人工智能方面的不平衡问题：**为最弱势群体（包括老年人）发起倡议活动，消除门槛，激发不同年龄和背景的学习者对人工智能的兴趣。

在人工智能时代培养生活和工作的价值观和技能

■ **建立预测模型，以确定就业和技能发展趋势，为面临人工智能自动化风险的工作制定再培训方案：**确定工作自动化的社会成本，提高公众对由此产生的国家和全球技能需求变化的认识。将全国的重点放在强化各级教育中面向未来的技能；提供技能再培训的途径，培养劳动力的适应力，以应对劳动力市场的系统性和长期转型。为年长工人提供特殊保护，因为年纪越大，学习新技能和适应新环境的能力就越弱。鼓励培训方案纳入对人工智能如何影响各职业的关注。

→ 示例

欧洲职业培训开发中心（CEDEFOP）技能预测：欧盟技能预测和准备工具：https://www.cedefop.europa.eu/en/publications-and- resources/data-visualisations/skills-forecast

■ **将人工智能相关技能纳入学校课程以及技术和职业教育与培训（TVET）资格：**修改课程，使学生为未来做好准备，确保这些改变与经济、劳动力市场和社会在所有学科和能力方面的变化相关联。制定课程、项目和资格鉴定方案，围绕人工智能技术如何运作、其伦理含义以及人工智能技术的设计方式，普及相关认识和专业知识。以教学研究和完善的方法论为基础，支持开发学习人工智能的工具。

→ 示例

Wekinator是由Rebecca Fiebrink创建的免费开源软件，用户可以使用机器学习构建新乐器、手势游戏控制器以及计算机视听系统：http://www.wekinator.org/

Teaching AI for K12，由联合国教科文组织和爱立信创建的门户网站，提供免费资源的链接，教师可以使用此类资源教授人工智能，还可以查询有关人工智能的部分信息：http://teachingaifork12.org

■ **采取机制提高社会各领域的人工智能素养：**向所有公民提供人工智能基础教育，指导其在人工智能背景下批判且负责任地思考其自身选择、权利、特权及其对日常生活的影响。告知他们如何保护自己的隐私，管控其自有数据和决策。教育大众认识人工智能的局限性，了解人工智能和人类智能之间的差异，消除有关人工智能的神话和炒作。细致整合新兴人工智能素养技能与现有基础技能，如媒体和信息素养，确定如何合并不同的必要素养，防止课程负担过重。

→ 示例

百分之一（1 Percent）：芬兰计划为其民众提供人工智能培训：https://www.politico.eu/article/finland-one-percent-ai-artificial-intelligence-courses-learning-training/

■ **帮助高等教育和研究机构培养本土人工智能人才：**制定计划，帮助高等教育和研究机构建立或强化培养本土人工智能人才的计划，并创建性别均衡的人才库，且存储的人才来自不同的社会经济背景，并具备设计人工智能系统的专业知识。开发专业硕士课程，重新培养人工智能工程师，并鼓励工程公司投资对劳动力进行人工智能再培训。

■ **留住本土人工智能人才：**激励人工智能公司立足本土发展；缓解工资与报酬的地区间差异；提供有意义的智力挑战，良好地平衡工作和生活之间的关系，从而留住人工智能专业人员。

→ 示例

“下一代人工智能（Next AI）”是在加拿大多伦多和蒙特利尔的校园内开展的项目，旨在找到高素质的团队，利用加拿大的资源，为他们提供必要的资本、指导、教育和网络：https://www.nextcanada.com/next-ai/；

中国政府的一项计划将培养至少500名人工智能教师和5,000名人工智能学生：https://www.ecns.cn/2018/04-07/298280.shtml

6.6 试验、监测和评估，建立实证库

建立可信的实证库，支持AI在教育中的应用

■ **测试并扩大将人工智能应用于学习的循证途径：**根据教育优先事项，而非采取新奇或炒作的方式，鼓励试点测试和循证采用人工智能增强的个性化学习模型、基于对话的导学系统、探索性学习系统、作文自动评阅系统、语言学习工具、基于人工智能的艺术品和音乐生成器、聊天机器人、增强和虚拟现实工具以及学习网络协调器等技术。鼓励采用促进学习环境开放性、探索性和多样性的人工智能工具。培养广泛的、可调动的能力，包括社交情感技能、元认知、协作、解决问题和创造力。确保人工智能在教育中的应用具有战略性（即具有长期的教学目标），而非短期的或临时的。

→ 示例

ITalk2Learn是为期三年的欧洲合作项目（2012年11月-2015年10月），旨在开发开源智能指导平台，为5至11周岁的学生学习数学提供支持：https://www.italk2learn.com/；

英国的**FractionsLab**，打造探索性学习环境，利用人工智能驱动的反馈，教导分数的学习：http://fractionslab.lkl.ac.uk；

由中国义学教育集团开发的**松鼠AI学习**，基于模式识别算法的自适应学习引擎：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，一套基于网络的音乐教育工具，支持音乐学习者的练习和发展：https://www.smartmusic.com/；

AIArtists.org，提供生成人工智能艺术的创造性工具：https://aiartists.org/ai-generated-art-tools

■ **根据以往教学研究和方法的经验，建立人工智能特定标准，以系统和严格地验证供应商关于人工智能潜力的声明：**制定人工智能具体标准，解决人类、社会和伦理关注问题，这些问题与在教育中应用人工智能的三大核心组成部分相关，即数据，算法分析和教育实践。

■ **促进人工智能系统的本土试点评估，评价其相关性和有效性：**对外部供应商提供的人工智能系统设计并实施大规模试点评估方案。测试其是否与当地环境相关，在教育实践、目标、多样性、文化和人口统计方面是否卓有成效。利用结果来定制人工智能系统的数据、设计和集成，以响应本土需求。监控系统的应用，以防止发生利益或合作冲突，以及与数据保护或所有权相关的分歧。

■ **计算并分析大规模利用人工智能技术的环境成本：**制定人工智能公司要达到的可持续目标，以避免造成气候变化和对自然环境的破坏。鼓励采取环保的方式，为大规模人工智能部署而生产所需的能源和资源。

加强人工智能与教育领域的研究和评估

■ **利用人工智能促进和改进教育研究和创新：**利用人工智能数据收集的实践和方法，以改进教育技术研究。从成功的案例中吸取经验，扩大循证实践。

■ **审查人工智能对教育的全面影响：**利用研究和审查过程，充分了解将人工智能纳入当地教育环境之后所产生的社会和伦理影响；对未知挑战和风险进行批判性审查，包括师生合作以及学生之间的协作关系发生的变化、社会动态变化等等。

■ **鼓励投资并提供有针对性的资金，以便为教育领域的人工智能构建循证生态系统：**激励和支持商业部门和高校开展人工智能应用程序的研究和开发，增强当地的知识技能，同时尽量减少既得利益的影响。

■ **在政府主导和企业主导发展领域以外的领域，为人工智能与教育的研究提供资金并采取激励措施：**在研究和高校环境中，保护本土人工智能教育专业知识的发展和拓展，并尽量减少既得利益对人工智能开发内容或其评估方式的影响。

→ 示例

由联合国教科文组织支持的**国际人工智能研究中心（IRCAI）**，其任务是进行人工智能的研究、宣传、能力建设和信息传播：https://ircai.org/

6.7 促进本土化教育人工智能技术创新

促进本土人工智能技术在教育领域的发展

■ **吸引企业投资，提供资金，创建实证库：**激励和支持开发以人为本的人工智能教育工具，聚集学习者、资助者、商业开发者、教育工作者和学习领域科学家，以应对市场失灵、全球教育实践的复杂性，以及推广各倡议计划所面临的挑战。

■ **推动创新，孵化人工智能技术和工具的本土开发：**协调专业知识、资源和能力，并在企业人工智能设计中利用实证性研究方法。对以消费者为目标的人工智能进行独立评估，鼓励未来人工智能一致向“以人为本”的方向发展。投资本土人才的教育和培训，并在投资网络之内，在能触及劳动力和消费市场的前提下，鼓励尝试在本土建立人工智能创业生态系统。参与国际合作，为大规模部署人工智能技术建立相关的资源和能力，从而开发本土化人工智能工具和专业知识。

→ 示例

IBM非洲研究实验室（IBM Research-Africa）是IBM的第12个全球研究实验室，也是非洲大陆上的首个工业研究机构。该实验室通过开发可行的解决方案来推动创新，改变人们的生活，并在教育等关键领域创造新的商业契机：https://www.research.ibm.com/labs/africa

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注

1 “AI for Peace”小组为政策制定者提供了更详细的非技术性指导: https://www.aiforpeace.org/library

2 100万的三次方等于1,000,000,000,000,000,000

3 计算能力需要大量能源，这对世界气候产生重大影响。

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

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

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

7 例如，研究人员将人工智能工具正确识别（偶有噪音）的熊猫图片遮盖起来。人还是能很容易识别出该图片为熊猫，但人工智能工具却将其识别为长臂猿。同样，在路标上随意粘贴一些小纸片（比如停车标志），导致自动驾驶车辆误判断。

8 首次介绍这种复杂性的开创性著作为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 使用聊天机器人回答客户的银行账户查询，表明银行领域也开始悄然发生变化（https://www.scmp.com/business/companies/article/2128179/hsbcs-amy-and-other-soon-be-released-ai-chatbots-are-about-change）。然而，谷歌备受争议的双工技术如今的智能化水平已然消沉。

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 例如，贝叶斯知识点追踪或绩效因素分析

34 Alef: https://alefeducation.com

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

36 Byjus: https://byjus.com（注：欧洲未提供）

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

38 Qubena: https://qubena.com

39 Riiid: https://riiidlabs.ai/

40 松鼠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 详见: https://theconversation.com/artificial-intelligence-can-now-emulate-human-behaviors-soon-it-will-be-dangerously-good-114136.关于人工智能可以“写”作业的早期实例，请参见https://openai.com/blog/better-language-models/#sample6

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

45 电脑评分（e-Rater）: https://www.ets.org/erater/about

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

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

48 人工智能教师: http://aiteacher.100tal.com

49 “神奇英语”利用人工智能帮助学生大声读英语。它还提供实时反馈以及人工智能驱动的评估。请参见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 多邻国: 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 开放的分布式账本，由互联网上数百万台计算机同时托管，并采用加密技术连接，能以可验证、不可破坏和可访问的方式共享数据。

66 例如Ada Lovelace研究所（https://www.adalovelaceinstitute.org）、人工智能伦理倡议(https://aiethicsinitiative.org)、人工智能伦理实验室（http://www.aiethicslab.com）、AI Now（https://ainowinstitute.org）、DeepMind伦理与社会（https://deepmind.com/applied/deepmind-ethics-society）和牛津互联网学院（https://www.oii.ox.ac.uk/blog/can-we-teach-morality-to-machines-three-perspec-tives-on-ethics-for-artificial-intelligence）。同时参见Winfield, Alan F. T., 和Jirotka, M. 2018。伦理道德治理对于建立对机器人技术和人工智能系统的信任至关重要。 Phil. Trans. R. Soc. A. 376.参见“人工智能的9大伦理问题”，网址：https://www.weforum.org/agenda/2016/10/top-10-ethical-issues-in-artificial-intelligence,“建立伦理人工智能道德准则难以想象”，网址：https://www.technologyreview.com/s/612318/establishing-an-ai-code-of-ethics-will-be-harder-than-people-think，以及 Willson, M. 2018。“培养理想的孩子? 算法、量化和预测。《媒体文化与社会》，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 例如，参见XPrize（https://learning.xprize.org）

69 https://digitallibrary.io

70 https://www.changedyslexia.org

71 如：http://www.voiceitt.com, https://www.nuance.com, https://otter.ai和https://kidsense.ai

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

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

74 为自闭症儿童开发的机器人实例为Kaspar（Dautenhahn等人，2009）

75 例如，参见Bughin等人，2017年；Frey和Osborne，2017年；前沿经济学，2018年；Leopold等人，2018年；Madgavkar等人，2019年；和Manyika等人，2017年；

76 万宝盛华集团。2016.“千禧代职业：2020年愿景-劳动力专家提供的事实、数字和实用建议”。网址：https://www.manpowergroup.com/wps/wcm/connect/660ebf65-144c-489e-975c-9f838294c237/MillennialsPaper1_2020Vision_lo.pdf?MOD=AJPERES

77 例如参见：（腾讯研究院，2017）全球人工智能人才白皮书

78 设计相关课程，使市民熟悉人工智能的工作原理，网址：https://www.elementsofai.com, https://okai.brown.edu and http://ai-4-all.org.

79 帮助教师向学生介绍人工智能的资源，详见：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

81 https://www.teensinai.com

82 https://www.skillsfuture.gov.sg/

83 https://microcompetencies.com

84 https://github.com/touretzkyds/ai4k12/wiki

85 http://teachingaifork12.org

86 https://www.elementsofai.com

87 https://okai.brown.edu

88 http://ai-4-all.org

89 https://www.oecd.ai/dashboards

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人工智能与教育

政策制定者指南

人工智能（Artificial Intelligence，AI）被视为实现可持续发展目标4进程的加速器。人工智能应用于教育的政策和策略对于实现人工智能对教育效益的最大化以及缓解其潜在风险至关重要。而政策制定过程的起点，就是要培养具备人工智能素养的政策制定者。

本出版物旨在为政策制定者提供理解人工智能的指南，帮助他们知晓如何应对人工智能给教育领域带来的挑战和机遇。具体而言，该出版物介绍了人工智能的必备知识，包括其定义、底层技术、技术应用、潜能和局限性。本出版物也剖析了一些借助人工智能增强教育和学习以及确保教育和学习的包容性和公平性等方面涌现出的实践案例，并对案例的效益和风险进行了评估。同时进一步阐明了教育在支持人类在与人工智能共处和合作方面做好准备的反向作用。

本出版物从现有政策实践中总结了三种政策应对模式，即独立模式、综合模式和专题模式。针对今后的工作，本出版物以2019年《北京共识——人工智能与教育》为准则，为人工智能与教育政策的规划提供了更为详细的建议和示例。

9 789235 000399

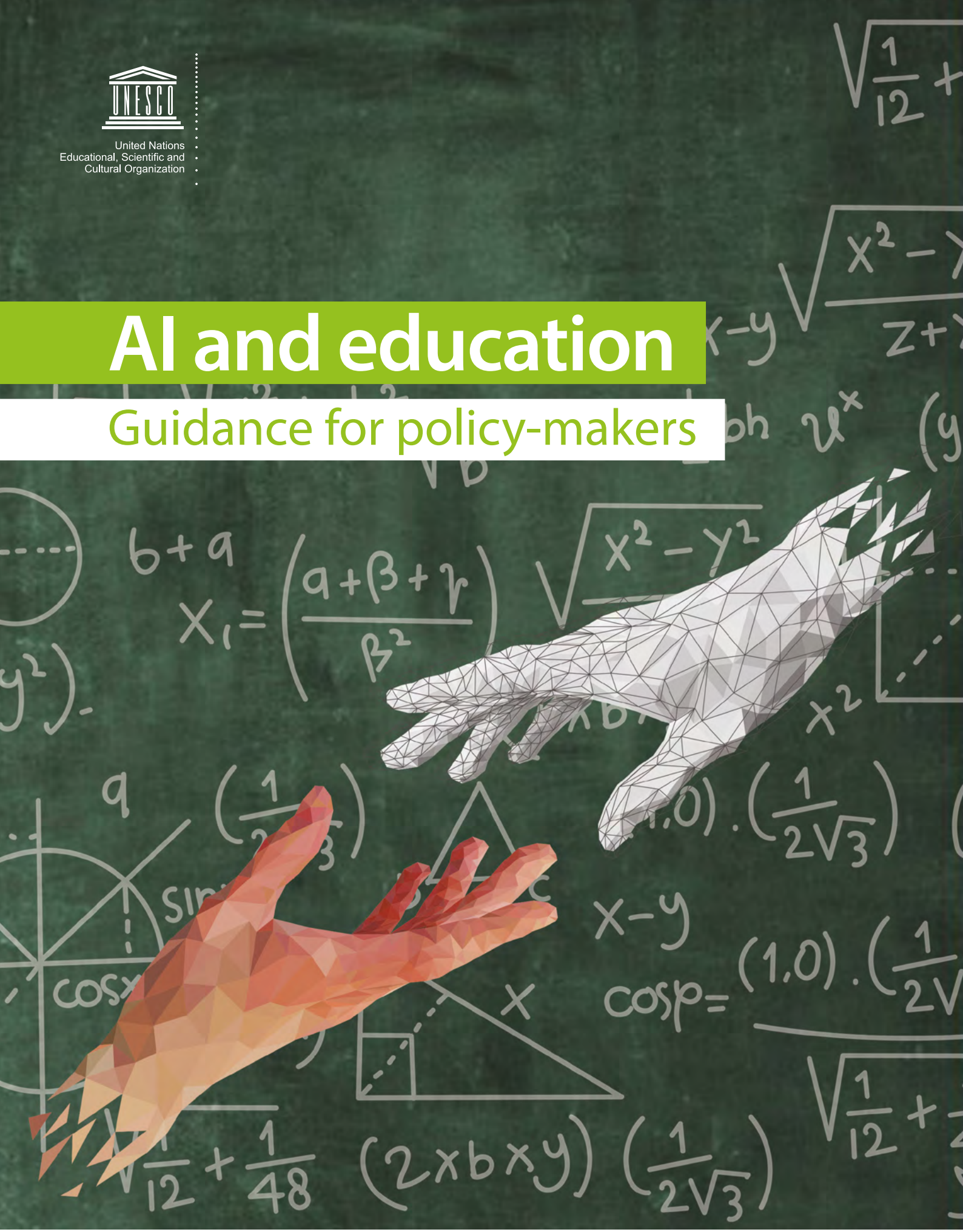
4 优质教育

可持续发展目标

United Nations
Educational, Scientific and
Cultural Organization

AI and education

Guidance for policy-makers



Education 2030

UNESCO Education Sector

Education is UNESCO's top priority because it is a basic human right and the foundation on which to build peace and drive sustainable development. UNESCO is the United Nations' specialized agency for education and the Education Sector provides global and regional leadership in education, strengthens national education systems and responds to contemporary global challenges through education with a special focus on gender equality and Africa.

The Global Education 2030 Agenda

UNESCO, as the United Nations' specialized agency for education, is entrusted to lead and coordinate the Education 2030 Agenda, which is part of a global movement to eradicate poverty through 17 Sustainable Development Goals by 2030. Education, essential to achieve all of these goals, has its own dedicated Goal 4, which aims to ***"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."*** The Education 2030 Framework for Action provides guidance for the implementation of this ambitious goal and commitments.

United Nations
Educational, Scientific and
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Education
Sector

Education 2030

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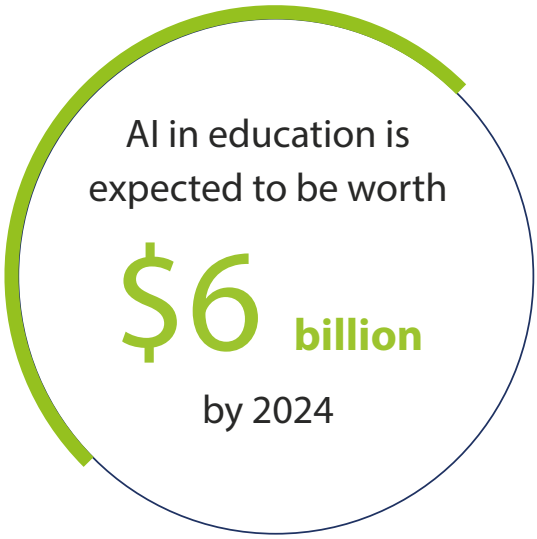
SHORT SUMMARY

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.



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.

'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.



Stefania Giannini
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

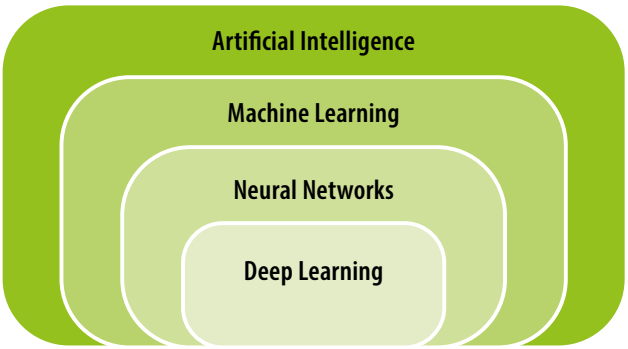
Much early or 'classical AI', variously known as 'symbolic AI', 'rule-based AI', or 'good-old-fashioned AI' ('GOFAI'), involves writing sequences of IF... THEN... and other rules of conditional logic, steps that the computer will take to complete a task. Over decades, rule-based AI 'expert systems' were 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.

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



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.

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 Khan 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?
- What pedagogical approaches are ethically warranted?

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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)

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.

Beijing Consensus on Artificial Intelligence and Education

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: S**et 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

81 https://www.teensinai.com

82 https://www.skillsfuture.gov.sg/

83 https://microcompetencies.com

84 https://github.com/touretzkyds/ai4k12/wiki

85 http://teachingaifork12.org

86 https://www.elementsofai.com

87 https://okai.brown.edu

88 http://ai-4-all.org

89 https://www.oecd.ai/dashboards

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Education Sector

United Nations Educational, Scientific and Cultural Organization

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

Recommendation on the ethics of artificial intelligence

PREAMBLE

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO), meeting in Paris from 9 to 24 November 2021, at its 41st session,

Recognizing the profound and dynamic positive and negative impacts of artificial intelligence (AI) on societies, environment, ecosystems and human lives, including the human mind, in part because of the new ways in which its use influences human thinking, interaction and decision-making and affects education, human, social and natural sciences, culture, and communication and information,

Recalling that, by the terms of its Constitution, UNESCO seeks to contribute to peace and security by promoting collaboration among nations through education, the sciences, culture, and communication and information, in order to further universal respect for justice, for the rule of law and for the human rights and fundamental freedoms which are affirmed for the peoples of the world,

Convinced that the Recommendation presented here, as a standard-setting instrument developed through a global approach, based on international law, focusing on human dignity and human rights, as well as gender equality, social and economic justice and development, physical and mental well-being, diversity, interconnectedness, inclusiveness, and environmental and ecosystem protection can guide AI technologies in a responsible direction,

Guided by the purposes and principles of the Charter of the United Nations,

Considering that AI technologies can be of great service to humanity and all countries can benefit from them, but also raise fundamental ethical concerns, for instance regarding the biases they can embed and exacerbate, potentially resulting in discrimination, inequality, digital divides, exclusion and a threat to cultural, social and biological diversity and social or economic divides; the need for transparency and understandability of the workings of algorithms and the data with which they have been trained; and their potential impact on, including but not limited to, human dignity, human rights and fundamental freedoms, gender equality, democracy, social, economic, political and cultural processes, scientific and engineering practices, animal welfare, and the environment and ecosystems,

Also recognizing that AI technologies can deepen existing divides and inequalities in the world, within and between countries, and that justice, trust and fairness must be upheld so that no country and no one should be left behind, either by having fair access to AI technologies and enjoying their benefits or in the protection against their negative implications, while recognizing the different circumstances of different countries and respecting the desire of some people not to take part in all technological developments,

Conscious of the fact that all countries are facing an acceleration in the use of information and communication technologies and AI technologies, as well as an increasing need for media and information literacy, and that the digital economy presents important societal, economic and environmental challenges and opportunities of benefit-sharing, especially for low- and middle-income countries (LMICs), including but not limited to least developed countries (LDCs), landlocked developing countries (LLDCs) and small island developing States (SIDS), requiring the recognition, protection and promotion of endogenous cultures, values and knowledge in order to develop sustainable digital economies,

Further recognizing that AI technologies have the potential to be beneficial to the environment and ecosystems, and in order for those benefits to be realized, potential harms to and negative impacts on the environment and ecosystems should not be ignored but instead addressed,

Noting that addressing risks and ethical concerns should not hamper innovation and development but rather provide new opportunities and stimulate ethically-conducted research and innovation that anchor AI technologies in human rights and fundamental freedoms, values and principles, and moral and ethical reflection,

Also recalling that in November 2019, the General Conference of UNESCO, at its 40th session, adopted 40 C/Resolution 37, by which it mandated the Director-General "to prepare an international standard-setting instrument on the ethics of artificial intelligence (AI) in the form of a recommendation", which is to be submitted to the General Conference at its 41st session in 2021,

Recognizing that the development of AI technologies necessitates a commensurate increase in data, media and information literacy as well as access to independent, pluralistic, trusted sources of information, including as part of efforts to mitigate risks of misinformation, disinformation and hate speech, and harm caused through the misuse of personal data,

Observing that a normative framework for AI technologies and its social implications finds its basis in international and national legal frameworks, human rights and fundamental freedoms, ethics, need for access to data, information and knowledge, the freedom of research and innovation, human and environmental and ecosystem well-being, and connects ethical values and principles to the challenges and opportunities linked to AI technologies, based on common understanding and shared aims,

Also recognizing that ethical values and principles can help develop and implement rights-based policy measures and legal norms, by providing guidance with a view to the fast pace of technological development,

Also convinced that globally accepted ethical standards for AI technologies, in full respect of international law, in particular human rights law, can play a key role in developing AI-related norms across the globe,

Bearing in mind the Universal Declaration of Human Rights (1948), the instruments of the international human rights framework, including the Convention Relating to the Status of Refugees (1951), the Discrimination (Employment and Occupation) Convention (1958), the International Convention on the Elimination of All Forms of Racial Discrimination (1965), the International Covenant on Civil and Political Rights (1966), the International Covenant on Economic, Social and Cultural Rights (1966), the Convention on the Elimination of All Forms of Discrimination against Women (1979), the Convention on the Rights of the Child (1989), and the Convention on the Rights of Persons with Disabilities (2006), the Convention against Discrimination in Education (1960), the Convention on the Protection and Promotion of the Diversity of Cultural Expressions (2005), as well as any other relevant international instruments, recommendations and declarations,

Also noting the United Nations Declaration on the Right to Development (1986); the Declaration on the Responsibilities of the Present Generations Towards Future Generations (1997); the Universal Declaration on Bioethics and Human Rights (2005); the United Nations Declaration on the Rights of Indigenous Peoples (2007); the United Nations General Assembly resolution on the review of the World Summit on the Information Society (A/RES/70/125) (2015); the United Nations General Assembly Resolution on Transforming our world: the 2030 Agenda for Sustainable Development (A/RES/70/1) (2015); the Recommendation Concerning the Preservation of, and Access to, Documentary Heritage Including in Digital Form (2015); the Declaration of Ethical Principles in relation to Climate Change (2017); the Recommendation on Science and Scientific Researchers (2017); the Internet Universality Indicators (endorsed by UNESCO's International Programme for the Development of Communication in 2018), including the ROAM principles (endorsed by UNESCO's General Conference in 2015); the Human Rights Council's resolution on "The right to privacy in the digital age" (A/HRC/RES/42/15) (2019); and the Human Rights Council's resolution on "New and emerging digital technologies and human rights" (A/HRC/RES/41/11) (2019),

Emphasizing that specific attention must be paid to LMICs, including but not limited to LDCs, LLDCs and SIDS, as they have their own capacity but have been underrepresented in the AI ethics debate, which raises concerns about neglecting local knowledge, cultural pluralism, value systems and the demands of global fairness to deal with the positive and negative impacts of AI technologies,

Also conscious of the many existing national policies, other frameworks and initiatives elaborated by relevant United Nations entities, intergovernmental organizations, including regional organizations, as well as those by the private sector, professional organizations, non-governmental organizations, and the scientific community, related to the ethics and regulation of AI technologies,

Further convinced that AI technologies can bring important benefits, but that achieving them can also amplify tension around innovation, asymmetric access to knowledge and technologies, including the digital and civic literacy deficit that limits the public's ability to engage in topics related to AI, as well as barriers to access to information and gaps in capacity, human and institutional capacities, barriers to access to technological

innovation, and a lack of adequate physical and digital infrastructure and regulatory frameworks, including those related to data, all of which need to be addressed,

Underlining that the strengthening of global cooperation and solidarity, including through multilateralism, is needed to facilitate fair access to AI technologies and address the challenges that they bring to diversity and interconnectivity of cultures and ethical systems, to mitigate potential misuse, to realize the full potential that AI can bring, especially in the area of development, and to ensure that national AI strategies are guided by ethical principles,

Taking fully into account that the rapid development of AI technologies challenges their ethical implementation and governance, as well as the respect for and protection of cultural diversity, and has the potential to disrupt local and regional ethical standards and values,

1. ***Adopts*** the present Recommendation on the Ethics of Artificial Intelligence on this twenty-third day of November 2021;

2. ***Recommends*** that Member States apply on a voluntary basis the provisions of this Recommendation by taking appropriate steps, including whatever legislative or other measures may be required, in conformity with the constitutional practice and governing structures of each State, to give effect within their jurisdictions to the principles and norms of the Recommendation in conformity with international law, including international human rights law;

3. ***Also recommends*** that Member States engage all stakeholders, including business enterprises, to ensure that they play their respective roles in the implementation of this Recommendation; and bring the Recommendation to the attention of the authorities, bodies, research and academic organizations, institutions and organizations in public, private and civil society sectors involved in AI technologies, so that the development and use of AI technologies are guided by both sound scientific research as well as ethical analysis and evaluation.

I. SCOPE OF APPLICATION

1. This Recommendation addresses ethical issues related to the domain of Artificial Intelligence to the extent that they are within UNESCO's mandate. It approaches AI ethics as a systematic normative reflection, based on a holistic, comprehensive, multicultural and evolving framework of interdependent values, principles and actions that can guide societies in dealing responsibly with the known and unknown impacts of AI technologies on human beings, societies and the environment and ecosystems, and offers them a basis to accept or reject AI technologies. It considers ethics as a dynamic basis for the normative evaluation and guidance of AI technologies, referring to human dignity, well-being and the prevention of harm as a compass and as rooted in the ethics of science and technology.

2. This Recommendation does not have the ambition to provide one single definition of AI, since such a definition would need to change over time, in accordance with technological developments. Rather, its ambition is to address those features of AI systems that are of central ethical relevance. Therefore, this Recommendation approaches AI systems as systems which have the capacity to process data and information in a way that resembles intelligent behaviour, and typically includes aspects of reasoning, learning, perception, prediction, planning or control. Three elements have a central place in this approach:

(a) AI systems are information-processing technologies that integrate models and algorithms that produce a capacity to learn and to perform cognitive tasks leading to outcomes such as prediction and decision-making in material and virtual environments. AI systems are designed to operate with varying degrees of autonomy by means of knowledge modelling and representation and by exploiting data and calculating correlations. AI systems may include several methods, such as but not limited to:

(i) machine learning, including deep learning and reinforcement learning;

(ii) machine reasoning, including planning, scheduling, knowledge representation and reasoning, search, and optimization.

AI systems can be used in cyber-physical systems, including the Internet of things, robotic systems, social robotics, and human-computer interfaces, which involve control, perception, the processing

of data collected by sensors, and the operation of actuators in the environment in which AI systems work.

(b) Ethical questions regarding AI systems pertain to all stages of the AI system life cycle, understood here to range from research, design and development to deployment and use, including maintenance, operation, trade, financing, monitoring and evaluation, validation, end-of-use, disassembly and termination. In addition, AI actors can be defined as any actor involved in at least one stage of the AI system life cycle, and can refer both to natural and legal persons, such as researchers, programmers, engineers, data scientists, end-users, business enterprises, universities and public and private entities, among others.

(c) AI systems raise new types of ethical issues that include, but are not limited to, their impact on decision-making, employment and labour, social interaction, health care, education, media, access to information, digital divide, personal data and consumer protection, environment, democracy, rule of law, security and policing, dual use, and human rights and fundamental freedoms, including freedom of expression, privacy and non-discrimination. Furthermore, new ethical challenges are created by the potential of AI algorithms to reproduce and reinforce existing biases, and thus to exacerbate already existing forms of discrimination, prejudice and stereotyping. Some of these issues are related to the capacity of AI systems to perform tasks which previously only living beings could do, and which were in some cases even limited to human beings only. These characteristics give AI systems a profound, new role in human practices and society, as well as in their relationship with the environment and ecosystems, creating a new context for children and young people to grow up in, develop an understanding of the world and themselves, critically understand media and information, and learn to make decisions. In the long term, AI systems could challenge humans' special sense of experience and agency, raising additional concerns about, inter alia, human self-understanding, social, cultural and environmental interaction, autonomy, agency, worth and dignity.

3. This Recommendation pays specific attention to the broader ethical implications of AI systems in relation to the central domains of UNESCO: education, science, culture, and communication and information, as explored in the 2019 Preliminary Study on the Ethics of Artificial Intelligence by the UNESCO World Commission on Ethics of Scientific Knowledge and Technology (COMEST):

(a) Education, because living in digitalizing societies requires new educational practices, ethical reflection, critical thinking, responsible design practices and new skills, given the implications for the labour market, employability and civic participation.

(b) Science, in the broadest sense and including all academic fields from the natural sciences and medical sciences to the social sciences and humanities, as AI technologies bring new research capacities and approaches, have implications for our concepts of scientific understanding and explanation, and create a new basis for decision-making.

(c) Cultural identity and diversity, as AI technologies can enrich cultural and creative industries, but can also lead to an increased concentration of supply of cultural content, data, markets and income in the hands of only a few actors, with potential negative implications for the diversity and pluralism of languages, media, cultural expressions, participation and equality.

(d) Communication and information, as AI technologies play an increasingly important role in the processing, structuring and provision of information; the issues of automated journalism and the algorithmic provision of news and moderation and curation of content on social media and search engines are just a few examples raising issues related to access to information, disinformation, misinformation, hate speech, the emergence of new forms of societal narratives, discrimination, freedom of expression, privacy and media and information literacy, among others.

4. This Recommendation is addressed to Member States, both as AI actors and as authorities responsible for developing legal and regulatory frameworks throughout the entire AI system life cycle, and for promoting business responsibility. It also provides ethical guidance to all AI actors, including the public and private sectors, by providing a basis for an ethical impact assessment of AI systems throughout their life cycle.

II. AIMS AND OBJECTIVES

5. This Recommendation aims to provide a basis to make AI systems work for the good of humanity, individuals, societies and the environment and ecosystems, and to prevent harm. It also aims at stimulating the peaceful use of AI systems.

6. In addition to the existing ethical frameworks regarding AI around the world, this Recommendation aims to bring a globally accepted normative instrument that focuses not only on the articulation of values and principles, but also on their practical realization, via concrete policy recommendations, with a strong emphasis on inclusion issues of gender equality and protection of the environment and ecosystems.

7. Because the complexity of the ethical issues surrounding AI necessitates the cooperation of multiple stakeholders across the various levels and sectors of international, regional and national communities, this Recommendation aims to enable stakeholders to take shared responsibility based on a global and intercultural dialogue.

8. The objectives of this Recommendation are:

(a) to provide a universal framework of values, principles and actions to guide States in the formulation of their legislation, policies or other instruments regarding AI, consistent with international law;

(b) to guide the actions of individuals, groups, communities, institutions and private sector companies to ensure the embedding of ethics in all stages of the AI system life cycle;

(c) to protect, promote and respect human rights and fundamental freedoms, human dignity and equality, including gender equality; to safeguard the interests of present and future generations; to preserve the environment, biodiversity and ecosystems; and to respect cultural diversity in all stages of the AI system life cycle;

(d) to foster multi-stakeholder, multidisciplinary and pluralistic dialogue and consensus building about ethical issues relating to AI systems;

(e) to promote equitable access to developments and knowledge in the field of AI and the sharing of benefits, with particular attention to the needs and contributions of LMICs, including LDCs, LLDCs and SIDS.

III. VALUES AND PRINCIPLES

9. The values and principles included below should be respected by all actors in the AI system life cycle, in the first place and, where needed and appropriate, be promoted through amendments to the existing and elaboration of new legislation, regulations and business guidelines. This must comply with international law, including the United Nations Charter and Member States' human rights obligations, and should be in line with internationally agreed social, political, environmental, educational, scientific and economic sustainability objectives, such as the United Nations Sustainable Development Goals (SDGs).

10. Values play a powerful role as motivating ideals in shaping policy measures and legal norms. While the set of values outlined below thus inspires desirable behaviour and represents the foundations of principles, the principles unpack the values underlying them more concretely so that the values can be more easily operationalized in policy statements and actions.

11. While all the values and principles outlined below are desirable per se, in any practical contexts, there may be tensions between these values and principles. In any given situation, a contextual assessment will be necessary to manage potential tensions, taking into account the principle of proportionality and in compliance with human rights and fundamental freedoms. In all cases, any possible limitations on human rights and fundamental freedoms must have a lawful basis, and be reasonable, necessary and proportionate, and consistent with States' obligations under international law. To navigate such scenarios judiciously will typically require engagement with a broad range of appropriate stakeholders, making use of social dialogue, as well as ethical deliberation, due diligence and impact assessment.

12. The trustworthiness and integrity of the life cycle of AI systems is essential to ensure that AI technologies will work for the good of humanity, individuals, societies and the environment and ecosystems, and embody

the values and principles set out in this Recommendation. People should have good reason to trust that AI systems can bring individual and shared benefits, while adequate measures are taken to mitigate risks. An essential requirement for trustworthiness is that, throughout their life cycle, AI systems are subject to thorough monitoring by the relevant stakeholders as appropriate. As trustworthiness is an outcome of the operationalization of the principles in this document, the policy actions proposed in this Recommendation are all directed at promoting trustworthiness in all stages of the AI system life cycle.

III.1 VALUES

Respect, protection and promotion of human rights and fundamental freedoms and human dignity

13. The inviolable and inherent dignity of every human constitutes the foundation for the universal, indivisible, inalienable, interdependent and interrelated system of human rights and fundamental freedoms. Therefore, respect, protection and promotion of human dignity and rights as established by international law, including international human rights law, is essential throughout the life cycle of AI systems. Human dignity relates to the recognition of the intrinsic and equal worth of each individual human being, regardless of race, colour, descent, gender, age, language, religion, political opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability and any other grounds.

14. No human being or human community should be harmed or subordinated, whether physically, economically, socially, politically, culturally or mentally during any phase of the life cycle of AI systems. Throughout the life cycle of AI systems, the quality of life of human beings should be enhanced, while the definition of “quality of life” should be left open to individuals or groups, as long as there is no violation or abuse of human rights and fundamental freedoms, or the dignity of humans in terms of this definition.

15. Persons may interact with AI systems throughout their life cycle and receive assistance from them, such as care for vulnerable people or people in vulnerable situations, including but not limited to children, older persons, persons with disabilities or the ill. Within such interactions, persons should never be objectified, nor should their dignity be otherwise undermined, or human rights and fundamental freedoms violated or abused.

16. Human rights and fundamental freedoms must be respected, protected and promoted throughout the life cycle of AI systems. Governments, private sector, civil society, international organizations, technical communities and academia must respect human rights instruments and frameworks in their interventions in the processes surrounding the life cycle of AI systems. New technologies need to provide new means to advocate, defend and exercise human rights and not to infringe them.

Environment and ecosystem flourishing

17. Environmental and ecosystem flourishing should be recognized, protected and promoted through the life cycle of AI systems. Furthermore, environment and ecosystems are the existential necessity for humanity and other living beings to be able to enjoy the benefits of advances in AI.

18. All actors involved in the life cycle of AI systems must comply with applicable international law and domestic legislation, standards and practices, such as precaution, designed for environmental and ecosystem protection and restoration, and sustainable development. They should reduce the environmental impact of AI systems, including but not limited to its carbon footprint, to ensure the minimization of climate change and environmental risk factors, and prevent the unsustainable exploitation, use and transformation of natural resources contributing to the deterioration of the environment and the degradation of ecosystems.

Ensuring diversity and inclusiveness

19. Respect, protection and promotion of diversity and inclusiveness should be ensured throughout the life cycle of AI systems, consistent with international law, including human rights law. This may be done by promoting active participation of all individuals or groups regardless of race, colour, descent, gender, age, language, religion, political opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability and any other grounds.

20. The scope of lifestyle choices, beliefs, opinions, expressions or personal experiences, including the optional use of AI systems and the co-design of these architectures should not be restricted during any phase of the life cycle of AI systems.

21. Furthermore, efforts, including international cooperation, should be made to overcome, and never take advantage of, the lack of necessary technological infrastructure, education and skills, as well as legal frameworks, particularly in LMICs, LDCs, LLDCs and SIDS, affecting communities.

Living in peaceful, just and interconnected societies

22. AI actors should play a participative and enabling role to ensure peaceful and just societies, which is based on an interconnected future for the benefit of all, consistent with human rights and fundamental freedoms. The value of living in peaceful and just societies points to the potential of AI systems to contribute throughout their life cycle to the interconnectedness of all living creatures with each other and with the natural environment.

23. The notion of humans being interconnected is based on the knowledge that every human belongs to a greater whole, which thrives when all its constituent parts are enabled to thrive. Living in peaceful, just and interconnected societies requires an organic, immediate, uncalculated bond of solidarity, characterized by a permanent search for peaceful relations, tending towards care for others and the natural environment in the broadest sense of the term.

24. This value demands that peace, inclusiveness and justice, equity and interconnectedness should be promoted throughout the life cycle of AI systems, in so far as the processes of the life cycle of AI systems should not segregate, objectify or undermine freedom and autonomous decision-making as well as the safety of human beings and communities, divide and turn individuals and groups against each other, or threaten the coexistence between humans, other living beings and the natural environment.

III.2 PRINCIPLES

Proportionality and Do No Harm

25. It should be recognized that AI technologies do not necessarily, per se, ensure human and environmental and ecosystem flourishing. Furthermore, none of the processes related to the AI system life cycle shall exceed what is necessary to achieve legitimate aims or objectives and should be appropriate to the context. In the event of possible occurrence of any harm to human beings, human rights and fundamental freedoms, communities and society at large or the environment and ecosystems, the implementation of procedures for risk assessment and the adoption of measures in order to preclude the occurrence of such harm should be ensured.

26. The choice to use AI systems and which AI method to use should be justified in the following ways: (a) the AI method chosen should be appropriate and proportional to achieve a given legitimate aim; (b) the AI method chosen should not infringe upon the foundational values captured in this document, in particular, its use must not violate or abuse human rights; and (c) the AI method should be appropriate to the context and should be based on rigorous scientific foundations. In scenarios where decisions are understood to have an impact that is irreversible or difficult to reverse or may involve life and death decisions, final human determination should apply. In particular, AI systems should not be used for social scoring or mass surveillance purposes.

Safety and security

27. Unwanted harms (safety risks), as well as vulnerabilities to attack (security risks) should be avoided and should be addressed, prevented and eliminated throughout the life cycle of AI systems to ensure human, environmental and ecosystem safety and security. Safe and secure AI will be enabled by the development of sustainable, privacy-protective data access frameworks that foster better training and validation of AI models utilizing quality data.

Fairness and non-discrimination

28. AI actors should promote social justice and safeguard fairness and non-discrimination of any kind in compliance with international law. This implies an inclusive approach to ensuring that the benefits of AI technologies are available and accessible to all, taking into consideration the specific needs of different age groups, cultural systems, different language groups, persons with disabilities, girls and women, and disadvantaged, marginalized and vulnerable people or people in vulnerable situations. Member States should work to promote inclusive access for all, including local communities, to AI systems with locally relevant content

and services, and with respect for multilingualism and cultural diversity. Member States should work to tackle digital divides and ensure inclusive access to and participation in the development of AI. At the national level, Member States should promote equity between rural and urban areas, and among all persons regardless of race, colour, descent, gender, age, language, religion, political opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability and any other grounds, in terms of access to and participation in the AI system life cycle. At the international level, the most technologically advanced countries have a responsibility of solidarity with the least advanced to ensure that the benefits of AI technologies are shared such that access to and participation in the AI system life cycle for the latter contributes to a fairer world order with regard to information, communication, culture, education, research and socio-economic and political stability.

29. AI actors should make all reasonable efforts to minimize and avoid reinforcing or perpetuating discriminatory or biased applications and outcomes throughout the life cycle of the AI system to ensure fairness of such systems. Effective remedy should be available against discrimination and biased algorithmic determination.

30. Furthermore, digital and knowledge divides within and between countries need to be addressed throughout an AI system life cycle, including in terms of access and quality of access to technology and data, in accordance with relevant national, regional and international legal frameworks, as well as in terms of connectivity, knowledge and skills and meaningful participation of the affected communities, such that every person is treated equitably.

Sustainability

31. The development of sustainable societies relies on the achievement of a complex set of objectives on a continuum of human, social, cultural, economic and environmental dimensions. The advent of AI technologies can either benefit sustainability objectives or hinder their realization, depending on how they are applied across countries with varying levels of development. The continuous assessment of the human, social, cultural, economic and environmental impact of AI technologies should therefore be carried out with full cognizance of the implications of AI technologies for sustainability as a set of constantly evolving goals across a range of dimensions, such as currently identified in the Sustainable Development Goals (SDGs) of the United Nations.

Right to Privacy, and Data Protection

32. Privacy, a right essential to the protection of human dignity, human autonomy and human agency, must be respected, protected and promoted throughout the life cycle of AI systems. It is important that data for AI systems be collected, used, shared, archived and deleted in ways that are consistent with international law and in line with the values and principles set forth in this Recommendation, while respecting relevant national, regional and international legal frameworks.

33. Adequate data protection frameworks and governance mechanisms should be established in a multi-stakeholder approach at the national or international level, protected by judicial systems, and ensured throughout the life cycle of AI systems. Data protection frameworks and any related mechanisms should take reference from international data protection principles and standards concerning the collection, use and disclosure of personal data and exercise of their rights by data subjects while ensuring a legitimate aim and a valid legal basis for the processing of personal data, including informed consent.

34. Algorithmic systems require adequate privacy impact assessments, which also include societal and ethical considerations of their use and an innovative use of the privacy by design approach. AI actors need to ensure that they are accountable for the design and implementation of AI systems in such a way as to ensure that personal information is protected throughout the life cycle of the AI system.

Human oversight and determination

35. Member States should ensure that it is always possible to attribute ethical and legal responsibility for any stage of the life cycle of AI systems, as well as in cases of remedy related to AI systems, to physical persons or to existing legal entities. Human oversight refers thus not only to individual human oversight, but to inclusive public oversight, as appropriate.

36. It may be the case that sometimes humans would choose to rely on AI systems for reasons of efficacy, but the decision to cede control in limited contexts remains that of humans, as humans can resort to AI systems

in decision-making and acting, but an AI system can never replace ultimate human responsibility and accountability. As a rule, life and death decisions should not be ceded to AI systems.

Transparency and explainability

37. The transparency and explainability of AI systems are often essential preconditions to ensure the respect, protection and promotion of human rights, fundamental freedoms and ethical principles. Transparency is necessary for relevant national and international liability regimes to work effectively. A lack of transparency could also undermine the possibility of effectively challenging decisions based on outcomes produced by AI systems and may thereby infringe the right to a fair trial and effective remedy, and limits the areas in which these systems can be legally used.

38. While efforts need to be made to increase transparency and explainability of AI systems, including those with extra-territorial impact, throughout their life cycle to support democratic governance, the level of transparency and explainability should always be appropriate to the context and impact, as there may be a need to balance between transparency and explainability and other principles such as privacy, safety and security. People should be fully informed when a decision is informed by or is made on the basis of AI algorithms, including when it affects their safety or human rights, and in those circumstances should have the opportunity to request explanatory information from the relevant AI actor or public sector institutions. In addition, individuals should be able to access the reasons for a decision affecting their rights and freedoms, and have the option of making submissions to a designated staff member of the private sector company or public sector institution able to review and correct the decision. AI actors should inform users when a product or service is provided directly or with the assistance of AI systems in a proper and timely manner.

39. From a socio-technical lens, greater transparency contributes to more peaceful, just, democratic and inclusive societies. It allows for public scrutiny that can decrease corruption and discrimination, and can also help detect and prevent negative impacts on human rights. Transparency aims at providing appropriate information to the respective addressees to enable their understanding and foster trust. Specific to the AI system, transparency can enable people to understand how each stage of an AI system is put in place, appropriate to the context and sensitivity of the AI system. It may also include insight into factors that affect a specific prediction or decision, and whether or not appropriate assurances (such as safety or fairness measures) are in place. In cases of serious threats of adverse human rights impacts, transparency may also require the sharing of code or datasets.

40. Explainability refers to making intelligible and providing insight into the outcome of AI systems. The explainability of AI systems also refers to the understandability of the input, output and the functioning of each algorithmic building block and how it contributes to the outcome of the systems. Thus, explainability is closely related to transparency, as outcomes and sub-processes leading to outcomes should aim to be understandable and traceable, appropriate to the context. AI actors should commit to ensuring that the algorithms developed are explainable. In the case of AI applications that impact the end user in a way that is not temporary, easily reversible or otherwise low risk, it should be ensured that the meaningful explanation is provided with any decision that resulted in the action taken in order for the outcome to be considered transparent.

41. Transparency and explainability relate closely to adequate responsibility and accountability measures, as well as to the trustworthiness of AI systems.

Responsibility and accountability

42. AI actors and Member States should respect, protect and promote human rights and fundamental freedoms, and should also promote the protection of the environment and ecosystems, assuming their respective ethical and legal responsibility, in accordance with national and international law, in particular Member States' human rights obligations, and ethical guidance throughout the life cycle of AI systems, including with respect to AI actors within their effective territory and control. The ethical responsibility and liability for the decisions and actions based in any way on an AI system should always ultimately be attributable to AI actors corresponding to their role in the life cycle of the AI system.

43. Appropriate oversight, impact assessment, audit and due diligence mechanisms, including whistle-blowers' protection, should be developed to ensure accountability for AI systems and their impact throughout their life cycle. Both technical and institutional designs should ensure auditability and traceability of (the

working of) AI systems in particular to address any conflicts with human rights norms and standards and threats to environmental and ecosystem well-being.

Awareness and literacy

44. Public awareness and understanding of AI technologies and the value of data should be promoted through open and accessible education, civic engagement, digital skills and AI ethics training, media and information literacy and training led jointly by governments, intergovernmental organizations, civil society, academia, the media, community leaders and the private sector, and considering the existing linguistic, social and cultural diversity, to ensure effective public participation so that all members of society can take informed decisions about their use of AI systems and be protected from undue influence.

45. Learning about the impact of AI systems should include learning about, through and for human rights and fundamental freedoms, meaning that the approach and understanding of AI systems should be grounded by their impact on human rights and access to rights, as well as on the environment and ecosystems.

Multi-stakeholder and adaptive governance and collaboration

46. International law and national sovereignty must be respected in the use of data. That means that States, complying with international law, can regulate the data generated within or passing through their territories, and take measures towards effective regulation of data, including data protection, based on respect for the right to privacy in accordance with international law and other human rights norms and standards.

47. Participation of different stakeholders throughout the AI system life cycle is necessary for inclusive approaches to AI governance, enabling the benefits to be shared by all, and to contribute to sustainable development. Stakeholders include but are not limited to governments, intergovernmental organizations, the technical community, civil society, researchers and academia, media, education, policy-makers, private sector companies, human rights institutions and equality bodies, anti-discrimination monitoring bodies, and groups for youth and children. The adoption of open standards and interoperability to facilitate collaboration should be in place. Measures should be adopted to take into account shifts in technologies, the emergence of new groups of stakeholders, and to allow for meaningful participation by marginalized groups, communities and individuals and, where relevant, in the case of Indigenous Peoples, respect for the self-governance of their data.

IV. AREAS OF POLICY ACTION

48. The policy actions described in the following policy areas operationalize the values and principles set out in this Recommendation. The main action is for Member States to put in place effective measures, including, for example, policy frameworks or mechanisms, and to ensure that other stakeholders, such as private sector companies, academic and research institutions, and civil society adhere to them by, among other actions, encouraging all stakeholders to develop human rights, rule of law, democracy, and ethical impact assessment and due diligence tools in line with guidance including the United Nations Guiding Principles on Business and Human Rights. The process for developing such policies or mechanisms should be inclusive of all stakeholders and should take into account the circumstances and priorities of each Member State. UNESCO can be a partner and support Member States in the development as well as monitoring and evaluation of policy mechanisms.

49. UNESCO recognizes that Member States will be at different stages of readiness to implement this Recommendation, in terms of scientific, technological, economic, educational, legal, regulatory, infrastructural, societal, cultural and other dimensions. It is noted that “readiness” here is a dynamic status. In order to enable the effective implementation of this Recommendation, UNESCO will therefore: (1) develop a readiness assessment methodology to assist interested Member States in identifying their status at specific moments of their readiness trajectory along a continuum of dimensions; and (2) ensure support for interested Member States in terms of developing a UNESCO methodology for Ethical Impact Assessment (EIA) of AI technologies, sharing of best practices, assessment guidelines and other mechanisms and analytical work.

POLICY AREA 1: ETHICAL IMPACT ASSESSMENT

50. Member States should introduce frameworks for impact assessments, such as ethical impact assessment, to identify and assess benefits, concerns and risks of AI systems, as well as appropriate risk prevention, mitigation and monitoring measures, among other assurance mechanisms. Such impact assessments should identify impacts on human rights and fundamental freedoms, in particular but not limited

to the rights of marginalized and vulnerable people or people in vulnerable situations, labour rights, the environment and ecosystems and ethical and social implications, and facilitate citizen participation in line with the values and principles set forth in this Recommendation.

51. Member States and private sector companies should develop due diligence and oversight mechanisms to identify, prevent, mitigate and account for how they address the impact of AI systems on the respect for human rights, rule of law and inclusive societies. Member States should also be able to assess the socio-economic impact of AI systems on poverty and ensure that the gap between people living in wealth and poverty, as well as the digital divide among and within countries, are not increased with the massive adoption of AI technologies at present and in the future. In order to do this, in particular, enforceable transparency protocols should be implemented, corresponding to the access to information, including information of public interest held by private entities. Member States, private sector companies and civil society should investigate the sociological and psychological effects of AI-based recommendations on humans in their decision-making autonomy. AI systems identified as potential risks to human rights should be broadly tested by AI actors, including in real-world conditions if needed, as part of the Ethical Impact Assessment, before releasing them in the market.

52. Member States and business enterprises should implement appropriate measures to monitor all phases of an AI system life cycle, including the functioning of algorithms used for decision-making, the data, as well as AI actors involved in the process, especially in public services and where direct end-user interaction is needed, as part of ethical impact assessment. Member States' human rights law obligations should form part of the ethical aspects of AI system assessments.

53. Governments should adopt a regulatory framework that sets out a procedure, particularly for public authorities, to carry out ethical impact assessments on AI systems to predict consequences, mitigate risks, avoid harmful consequences, facilitate citizen participation and address societal challenges. The assessment should also establish appropriate oversight mechanisms, including auditability, traceability and explainability, which enable the assessment of algorithms, data and design processes, as well as include external review of AI systems. Ethical impact assessments should be transparent and open to the public, where appropriate. Such assessments should also be multidisciplinary, multi-stakeholder, multicultural, pluralistic and inclusive. The public authorities should be required to monitor the AI systems implemented and/or deployed by those authorities by introducing appropriate mechanisms and tools.

POLICY AREA 2: ETHICAL GOVERNANCE AND STEWARDSHIP

54. Member States should ensure that AI governance mechanisms are inclusive, transparent, multidisciplinary, multilateral (this includes the possibility of mitigation and redress of harm across borders) and multi-stakeholder. In particular, governance should include aspects of anticipation, and effective protection, monitoring of impact, enforcement and redress.

55. Member States should ensure that harms caused through AI systems are investigated and redressed, by enacting strong enforcement mechanisms and remedial actions, to make certain that human rights and fundamental freedoms and the rule of law are respected in the digital world and in the physical world. Such mechanisms and actions should include remediation mechanisms provided by private and public sector companies. The auditability and traceability of AI systems should be promoted to this end. In addition, Member States should strengthen their institutional capacities to deliver on this commitment and should collaborate with researchers and other stakeholders to investigate, prevent and mitigate any potentially malicious uses of AI systems.

56. Member States are encouraged to develop national and regional AI strategies and to consider forms of soft governance such as a certification mechanism for AI systems and the mutual recognition of their certification, according to the sensitivity of the application domain and expected impact on human rights, the environment and ecosystems, and other ethical considerations set forth in this Recommendation. Such a mechanism might include different levels of audit of systems, data, and adherence to ethical guidelines and to procedural requirements in view of ethical aspects. At the same time, such a mechanism should not hinder innovation or disadvantage small and medium enterprises or start-ups, civil society as well as research and science organizations, as a result of an excessive administrative burden. These mechanisms should also include a regular monitoring component to ensure system robustness and continued integrity and adherence to ethical guidelines over the entire life cycle of the AI system, requiring re-certification if necessary.

57. Member States and public authorities should carry out transparent self-assessment of existing and proposed AI systems, which, in particular, should include the assessment of whether the adoption of AI is appropriate and, if so, should include further assessment to determine what the appropriate method is, as well as assessment as to whether such adoption would result in violations or abuses of Member States' human rights law obligations, and if that is the case, prohibit its use.

58. Member States should encourage public entities, private sector companies and civil society organizations to involve different stakeholders in their AI governance and to consider adding the role of an independent AI Ethics Officer or some other mechanism to oversee ethical impact assessment, auditing and continuous monitoring efforts and ensure ethical guidance of AI systems. Member States, private sector companies and civil society organizations, with the support of UNESCO, are encouraged to create a network of independent AI Ethics Officers to give support to this process at national, regional and international levels.

59. Member States should foster the development of, and access to, a digital ecosystem for ethical and inclusive development of AI systems at the national level, including to address gaps in access to the AI system life cycle, while contributing to international collaboration. Such an ecosystem includes, in particular, digital technologies and infrastructure, and mechanisms for sharing AI knowledge, as appropriate.

60. Member States should establish mechanisms, in collaboration with international organizations, transnational corporations, academic institutions and civil society, to ensure the active participation of all Member States, especially LMICs, in particular LDCs, LLDCs and SIDS, in international discussions concerning AI governance. This can be through the provision of funds, ensuring equal regional participation, or any other mechanisms. Furthermore, in order to ensure the inclusiveness of AI fora, Member States should facilitate the travel of AI actors in and out of their territory, especially from LMICs, in particular LDCs, LLDCs and SIDS, for the purpose of participating in these fora.

61. Amendments to the existing or elaboration of new national legislation addressing AI systems must comply with Member States' human rights law obligations and promote human rights and fundamental freedoms throughout the AI system life cycle. Promotion thereof should also take the form of governance initiatives, good exemplars of collaborative practices regarding AI systems, and national and international technical and methodological guidelines as AI technologies advance. Diverse sectors, including the private sector, in their practices regarding AI systems must respect, protect and promote human rights and fundamental freedoms using existing and new instruments in combination with this Recommendation.

62. Member States that acquire AI systems for human rights-sensitive use cases, such as law enforcement, welfare, employment, media and information providers, health care and the independent judiciary system should provide mechanisms to monitor the social and economic impact of such systems by appropriate oversight authorities, including independent data protection authorities, sectoral oversight and public bodies responsible for oversight.

63. Member States should enhance the capacity of the judiciary to make decisions related to AI systems as per the rule of law and in line with international law and standards, including in the use of AI systems in their deliberations, while ensuring that the principle of human oversight is upheld. In case AI systems are used by the judiciary, sufficient safeguards are needed to guarantee inter alia the protection of fundamental human rights, the rule of law, judicial independence as well as the principle of human oversight, and to ensure a trustworthy, public interest-oriented and human-centric development and use of AI systems in the judiciary.

64. Member States should ensure that governments and multilateral organizations play a leading role in ensuring the safety and security of AI systems, with multi-stakeholder participation. Specifically, Member States, international organizations and other relevant bodies should develop international standards that describe measurable, testable levels of safety and transparency, so that systems can be objectively assessed and levels of compliance determined. Furthermore, Member States and business enterprises should continuously support strategic research on potential safety and security risks of AI technologies and should encourage research into transparency and explainability, inclusion and literacy by putting additional funding into those areas for different domains and at different levels, such as technical and natural language.

65. Member States should implement policies to ensure that the actions of AI actors are consistent with international human rights law, standards and principles throughout the life cycle of AI systems, while taking into full consideration the current cultural and social diversities, including local customs and religious traditions, with due regard to the precedence and universality of human rights.

66. Member States should put in place mechanisms to require AI actors to disclose and combat any kind of stereotyping in the outcomes of AI systems and data, whether by design or by negligence, and to ensure that training data sets for AI systems do not foster cultural, economic or social inequalities, prejudice, the spreading of disinformation and misinformation, and disruption of freedom of expression and access to information. Particular attention should be given to regions where the data are scarce.

67. Member States should implement policies to promote and increase diversity and inclusiveness that reflect their populations in AI development teams and training datasets, and to ensure equal access to AI technologies and their benefits, particularly for marginalized groups, both from rural and urban zones.

68. Member States should develop, review and adapt, as appropriate, regulatory frameworks to achieve accountability and responsibility for the content and outcomes of AI systems at the different phases of their life cycle. Member States should, where necessary, introduce liability frameworks or clarify the interpretation of existing frameworks to ensure the attribution of accountability for the outcomes and the functioning of AI systems. Furthermore, when developing regulatory frameworks, Member States should, in particular, take into account that ultimate responsibility and accountability must always lie with natural or legal persons and that AI systems should not be given legal personality themselves. To ensure this, such regulatory frameworks should be consistent with the principle of human oversight and establish a comprehensive approach focused on AI actors and the technological processes involved across the different stages of the AI system life cycle.

69. In order to establish norms where these do not exist, or to adapt the existing legal frameworks, Member States should involve all AI actors (including, but not limited to, researchers, representatives of civil society and law enforcement, insurers, investors, manufacturers, engineers, lawyers and users). The norms can mature into best practices, laws and regulations. Member States are further encouraged to use mechanisms such as policy prototypes and regulatory sandboxes to accelerate the development of laws, regulations and policies, including regular reviews thereof, in line with the rapid development of new technologies and ensure that laws and regulations can be tested in a safe environment before being officially adopted. Member States should support local governments in the development of local policies, regulations and laws in line with national and international legal frameworks.

70. Member States should set clear requirements for AI system transparency and explainability so as to help ensure the trustworthiness of the full AI system life cycle. Such requirements should involve the design and implementation of impact mechanisms that take into consideration the nature of application domain, intended use, target audience and feasibility of each particular AI system.

POLICY AREA 3: DATA POLICY

71. Member States should work to develop data governance strategies that ensure the continual evaluation of the quality of training data for AI systems including the adequacy of the data collection and selection processes, proper data security and protection measures, as well as feedback mechanisms to learn from mistakes and share best practices among all AI actors.

72. Member States should put in place appropriate safeguards to protect the right to privacy in accordance with international law, including addressing concerns such as surveillance. Member States should, among others, adopt or enforce legislative frameworks that provide appropriate protection, compliant with international law. Member States should strongly encourage all AI actors, including business enterprises, to follow existing international standards and, in particular, to carry out adequate privacy impact assessments, as part of ethical impact assessments, which take into account the wider socio-economic impact of the intended data processing, and to apply privacy by design in their systems. Privacy should be respected, protected and promoted throughout the life cycle of AI systems.

73. Member States should ensure that individuals retain rights over their personal data and are protected by a framework, which notably foresees: transparency; appropriate safeguards for the processing of sensitive data; an appropriate level of data protection; effective and meaningful accountability schemes and mechanisms; the full enjoyment of the data subjects' rights and the ability to access and erase their personal data in AI systems, except for certain circumstances in compliance with international law; an appropriate level of protection in full compliance with data protection legislation where data are being used for commercial purposes such as enabling micro-targeted advertising, transferred cross-border; and an effective independent oversight as part of a data governance mechanism which keeps individuals in control of their personal data and fosters the benefits of a free flow of information internationally, including access to data.

74. Member States should establish their data policies or equivalent frameworks, or reinforce existing ones, to ensure full security for personal data and sensitive data, which, if disclosed, may cause exceptional damage, injury or hardship to individuals. Examples include data relating to offences, criminal proceedings and convictions, and related security measures; biometric, genetic and health data; and -personal data such as that relating to race, colour, descent, gender, age, language, religion, political opinion, national origin, ethnic origin, social origin, economic or social condition of birth, or disability and any other characteristics.

75. Member States should promote open data. In this regard, Member States should consider reviewing their policies and regulatory frameworks, including on access to information and open government to reflect AI-specific requirements and promoting mechanisms, such as open repositories for publicly funded or publicly held data and source code and data trusts, to support the safe, fair, legal and ethical sharing of data, among others.

76. Member States should promote and facilitate the use of quality and robust datasets for training, development and use of AI systems, and exercise vigilance in overseeing their collection and use. This could, if possible and feasible, include investing in the creation of gold standard datasets, including open and trustworthy datasets, which are diverse, constructed on a valid legal basis, including consent of data subjects, when required by law. Standards for annotating datasets should be encouraged, including disaggregating data on gender and other bases, so it can easily be determined how a dataset is gathered and what properties it has.

77. Member States, as also suggested in the report of the United Nations Secretary-General's High-level Panel on Digital Cooperation, with the support of the United Nations and UNESCO, should adopt a digital commons approach to data where appropriate, increase interoperability of tools and datasets and interfaces of systems hosting data, and encourage private sector companies to share the data they collect with all stakeholders, as appropriate, for research, innovation or public benefits. They should also promote public and private efforts to create collaborative platforms to share quality data in trusted and secured data spaces.

POLICY AREA 4: DEVELOPMENT AND INTERNATIONAL COOPERATION

78. Member States and transnational corporations should prioritize AI ethics by including discussions of AI-related ethical issues into relevant international, intergovernmental and multi-stakeholder fora.

79. Member States should ensure that the use of AI in areas of development such as education, science, culture, communication and information, health care, agriculture and food supply, environment, natural resource and infrastructure management, economic planning and growth, among others, adheres to the values and principles set forth in this Recommendation.

80. Member States should work through international organizations to provide platforms for international cooperation on AI for development, including by contributing expertise, funding, data, domain knowledge, infrastructure, and facilitating multi-stakeholder collaboration to tackle challenging development problems, especially for LMICs, in particular LDCs, LLDCs and SIDS.

81. Member States should work to promote international collaboration on AI research and innovation, including research and innovation centres and networks that promote greater participation and leadership of researchers from LMICs and other countries, including LDCs, LLDCs and SIDS.

82. Member States should promote AI ethics research by engaging international organizations and research institutions, as well as transnational corporations, that can be a basis for the ethical use of AI systems by public and private entities, including research into the applicability of specific ethical frameworks in specific cultures and contexts, and the possibilities to develop technologically feasible solutions in line with these frameworks.

83. Member States should encourage international cooperation and collaboration in the field of AI to bridge geo-technological lines. Technological exchanges and consultations should take place between Member States and their populations, between the public and private sectors, and between and among the most and least technologically advanced countries in full respect of international law.

POLICY AREA 5: ENVIRONMENT AND ECOSYSTEMS

84. Member States and business enterprises should assess the direct and indirect environmental impact throughout the AI system life cycle, including, but not limited to, its carbon footprint, energy consumption and

the environmental impact of raw material extraction for supporting the manufacturing of AI technologies, and reduce the environmental impact of AI systems and data infrastructures. Member States should ensure compliance of all AI actors with environmental law, policies and practices.

85. Member States should introduce incentives, when needed and appropriate, to ensure the development and adoption of rights-based and ethical AI-powered solutions for disaster risk resilience; the monitoring, protection and regeneration of the environment and ecosystems; and the preservation of the planet. These AI systems should involve the participation of local and indigenous communities throughout the life cycle of AI systems and should support circular economy type approaches and sustainable consumption and production patterns. Some examples include using AI systems, when needed and appropriate, to:

(a) Support the protection, monitoring and management of natural resources.

(b) Support the prediction, prevention, control and mitigation of climate-related problems.

(c) Support a more efficient and sustainable food ecosystem.

(d) Support the acceleration of access to and mass adoption of sustainable energy.

(e) Enable and promote the mainstreaming of sustainable infrastructure, sustainable business models and sustainable finance for sustainable development.

(f) Detect pollutants or predict levels of pollution and thus help relevant stakeholders identify, plan and put in place targeted interventions to prevent and reduce pollution and exposure.

86. When choosing AI methods, given the potential data-intensive or resource-intensive character of some of them and the respective impact on the environment, Member States should ensure that AI actors, in line with the principle of proportionality, favour data, energy and resource-efficient AI methods. Requirements should be developed to ensure that appropriate evidence is available to show that an AI application will have the intended effect, or that safeguards accompanying an AI application can support the justification for its use. If this cannot be done, the precautionary principle must be favoured, and in instances where there are disproportionate negative impacts on the environment, AI should not be used.

POLICY AREA 6: GENDER

87. Member States should ensure that the potential for digital technologies and artificial intelligence to contribute to achieving gender equality is fully maximized, and must ensure that the human rights and fundamental freedoms of girls and women, and their safety and integrity are not violated at any stage of the AI system life cycle. Moreover, Ethical Impact Assessment should include a transversal gender perspective.

88. Member States should have dedicated funds from their public budgets linked to financing gender-responsive schemes, ensure that national digital policies include a gender action plan, and develop relevant policies, for example, on labour education, targeted at supporting girls and women to make sure they are not left out of the digital economy powered by AI. Special investment in providing targeted programmes and gender-specific language, to increase the opportunities of girls' and women's participation in science, technology, engineering, and mathematics (STEM), including information and communication technologies (ICT) disciplines, preparedness, employability, equal career development and professional growth of girls and women, should be considered and implemented.

89. Member States should ensure that the potential of AI systems to advance the achievement of gender equality is realized. They should ensure that these technologies do not exacerbate the already wide gender gaps existing in several fields in the analogue world, and instead eliminate those gaps. These gaps include: the gender wage gap; the unequal representation in certain professions and activities; the lack of representation at top management positions, boards of directors, or research teams in the AI field; the education gap; the digital and AI access, adoption, usage and affordability gap; and the unequal distribution of unpaid work and of the caring responsibilities in our societies.

90. Member States should ensure that gender stereotyping and discriminatory biases are not translated into AI systems, and instead identify and proactively redress these. Efforts are necessary to avoid the compounding negative effect of technological divides in achieving gender equality and avoiding violence such as harassment, bullying or trafficking of girls and women and under-represented groups, including in the online domain.

91. Member States should encourage female entrepreneurship, participation and engagement in all stages of an AI system life cycle by offering and promoting economic, regulatory incentives, among other incentives and support schemes, as well as policies that aim at a balanced gender participation in AI research in academia, gender representation on digital and AI companies' top management positions, boards of directors and research teams. Member States should ensure that public funds (for innovation, research and technologies) are channelled to inclusive programmes and companies, with clear gender representation, and that private funds are similarly encouraged through affirmative action principles. Policies on harassment-free environments should be developed and enforced, together with the encouragement of the transfer of best practices on how to promote diversity throughout the AI system life cycle.

92. Member States should promote gender diversity in AI research in academia and industry by offering incentives to girls and women to enter the field, putting in place mechanisms to fight gender stereotyping and harassment within the AI research community, and encouraging academic and private entities to share best practices on how to enhance gender diversity.

93. UNESCO can help form a repository of best practices for incentivizing the participation of girls, women and under-represented groups in all stages of the AI system life cycle.

POLICY AREA 7: CULTURE

94. Member States are encouraged to incorporate AI systems, where appropriate, in the preservation, enrichment, understanding, promotion, management and accessibility of tangible, documentary and intangible cultural heritage, including endangered languages as well as indigenous languages and knowledges, for example by introducing or updating educational programmes related to the application of AI systems in these areas, where appropriate, and by ensuring a participatory approach, targeted at institutions and the public.

95. Member States are encouraged to examine and address the cultural impact of AI systems, especially natural language processing (NLP) applications such as automated translation and voice assistants, on the nuances of human language and expression. Such assessments should provide input for the design and implementation of strategies that maximize the benefits from these systems by bridging cultural gaps and increasing human understanding, as well as addressing the negative implications such as the reduction of use, which could lead to the disappearance of endangered languages, local dialects, and tonal and cultural variations associated with human language and expression.

96. Member States should promote AI education and digital training for artists and creative professionals to assess the suitability of AI technologies for use in their profession, and contribute to the design and implementation of suitable AI technologies, as AI technologies are being used to create, produce, distribute, broadcast and consume a variety of cultural goods and services, bearing in mind the importance of preserving cultural heritage, diversity and artistic freedom.

97. Member States should promote awareness and evaluation of AI tools among local cultural industries and small and medium enterprises working in the field of culture, to avoid the risk of concentration in the cultural market.

98. Member States should engage technology companies and other stakeholders to promote a diverse supply of and plural access to cultural expressions, and in particular to ensure that algorithmic recommendation enhances the visibility and discoverability of local content.

99. Member States should foster new research at the intersection between AI and intellectual property (IP), for example to determine whether or how to protect with IP rights the works created by means of AI technologies. Member States should also assess how AI technologies are affecting the rights or interests of IP owners, whose works are used to research, develop, train or implement AI applications.

100. Member States should encourage museums, galleries, libraries and archives at the national level to use AI systems to highlight their collections and enhance their libraries, databases and knowledge base, while also providing access to their users.

POLICY AREA 8: EDUCATION AND RESEARCH

101. Member States should work with international organizations, educational institutions and private and non-governmental entities to provide adequate AI literacy education to the public on all levels in all countries

in order to empower people and reduce the digital divides and digital access inequalities resulting from the wide adoption of AI systems.

102. Member States should promote the acquisition of “prerequisite skills” for AI education, such as basic literacy, numeracy, coding and digital skills, and media and information literacy, as well as critical and creative thinking, teamwork, communication, socio-emotional and AI ethics skills, especially in countries and in regions or areas within countries where there are notable gaps in the education of these skills.

103. Member States should promote general awareness programmes about AI developments, including on data and the opportunities and challenges brought about by AI technologies, the impact of AI systems on human rights and their implications, including children’s rights. These programmes should be accessible to non-technical as well as technical groups.

104. Member States should encourage research initiatives on the responsible and ethical use of AI technologies in teaching, teacher training and e-learning, among other issues, to enhance opportunities and mitigate the challenges and risks involved in this area. The initiatives should be accompanied by an adequate assessment of the quality of education and impact on students and teachers of the use of AI technologies. Member States should also ensure that AI technologies empower students and teachers and enhance their experience, bearing in mind that relational and social aspects and the value of traditional forms of education are vital in teacher-student and student-student relationships and should be considered when discussing the adoption of AI technologies in education. AI systems used in learning should be subject to strict requirements when it comes to the monitoring, assessment of abilities, or prediction of the learners’ behaviours. AI should support the learning process without reducing cognitive abilities and without extracting sensitive information, in compliance with relevant personal data protection standards. The data handed over to acquire knowledge collected during the learner’s interactions with the AI system must not be subject to misuse, misappropriation or criminal exploitation, including for commercial purposes.

105. Member States should promote the participation and leadership of girls and women, diverse ethnicities and cultures, persons with disabilities, marginalized and vulnerable people or people in vulnerable situations, minorities and all persons not enjoying the full benefits of digital inclusion, in AI education programmes at all levels, as well as the monitoring and sharing of best practices in this regard with other Member States.

106. Member States should develop, in accordance with their national education programmes and traditions, AI ethics curricula for all levels, and promote cross-collaboration between AI technical skills education and humanistic, ethical and social aspects of AI education. Online courses and digital resources of AI ethics education should be developed in local languages, including indigenous languages, and take into account the diversity of environments, especially ensuring accessibility of formats for persons with disabilities.

107. Member States should promote and support AI research, notably AI ethics research, including for example through investing in such research or by creating incentives for the public and private sectors to invest in this area, recognizing that research contributes significantly to the further development and improvement of AI technologies with a view to promoting international law and the values and principles set forth in this Recommendation. Member States should also publicly promote the best practices of, and cooperation with, researchers and companies who develop AI in an ethical manner.

108. Member States should ensure that AI researchers are trained in research ethics and require them to include ethical considerations in their designs, products and publications, especially in the analyses of the datasets they use, how they are annotated, and the quality and scope of the results with possible applications.

109. Member States should encourage private sector companies to facilitate the access of the scientific community to their data for research, especially in LMICs, in particular LDCs, LLDCs and SIDS. This access should conform to relevant privacy and data protection standards.

110. To ensure a critical evaluation of AI research and proper monitoring of potential misuses or adverse effects, Member States should ensure that any future developments with regards to AI technologies should be based on rigorous and independent scientific research, and promote interdisciplinary AI research by including disciplines other than science, technology, engineering and mathematics (STEM), such as cultural studies, education, ethics, international relations, law, linguistics, philosophy, political science, sociology and psychology.

111. Recognizing that AI technologies present great opportunities to help advance scientific knowledge and practice, especially in traditionally model-driven disciplines, Member States should encourage scientific communities to be aware of the benefits, limits and risks of their use; this includes attempting to ensure that conclusions drawn from data-driven approaches, models and treatments are robust and sound. Furthermore, Member States should welcome and support the role of the scientific community in contributing to policy and in cultivating awareness of the strengths and weaknesses of AI technologies.

POLICY AREA 9: COMMUNICATION AND INFORMATION

112. Member States should use AI systems to improve access to information and knowledge. This can include support to researchers, academia, journalists, the general public and developers, to enhance freedom of expression, academic and scientific freedoms, access to information, and increased proactive disclosure of official data and information.

113. Member States should ensure that AI actors respect and promote freedom of expression as well as access to information with regard to automated content generation, moderation and curation. Appropriate frameworks, including regulation, should enable transparency of online communication and information operators and ensure users have access to a diversity of viewpoints, as well as processes for prompt notification to the users on the reasons for removal or other treatment of content, and appeal mechanisms that allow users to seek redress.

114. Member States should invest in and promote digital and media and information literacy skills to strengthen critical thinking and competencies needed to understand the use and implication of AI systems, in order to mitigate and counter disinformation, misinformation and hate speech. A better understanding and evaluation of both the positive and potentially harmful effects of recommender systems should be part of those efforts.

115. Member States should create enabling environments for media to have the rights and resources to effectively report on the benefits and harms of AI systems, and also encourage media to make ethical use of AI systems in their operations.

POLICY AREA 10: ECONOMY AND LABOUR

116. Member States should assess and address the impact of AI systems on labour markets and its implications for education requirements, in all countries and with special emphasis on countries where the economy is labour-intensive. This can include the introduction of a wider range of “core” and interdisciplinary skills at all education levels to provide current workers and new generations a fair chance of finding jobs in a rapidly changing market, and to ensure their awareness of the ethical aspects of AI systems. Skills such as “learning how to learn”, communication, critical thinking, teamwork, empathy, and the ability to transfer one’s knowledge across domains, should be taught alongside specialist, technical skills, as well as low-skilled tasks. Being transparent about what skills are in demand and updating curricula around these are key.

117. Member States should support collaboration agreements among governments, academic institutions, vocational education and training institutions, industry, workers’ organizations and civil society to bridge the gap of skillset requirements to align training programmes and strategies with the implications of the future of work and the needs of industry, including small and medium enterprises. Project-based teaching and learning approaches for AI should be promoted, allowing for partnerships between public institutions, private sector companies, universities and research centres.

118. Member States should work with private sector companies, civil society organizations and other stakeholders, including workers and unions to ensure a fair transition for at-risk employees. This includes putting in place upskilling and reskilling programmes, finding effective mechanisms of retaining employees during those transition periods, and exploring “safety net” programmes for those who cannot be retrained. Member States should develop and implement programmes to research and address the challenges identified that could include upskilling and reskilling, enhanced social protection, proactive industry policies and interventions, tax benefits, new taxation forms, among others. Member States should ensure that there is sufficient public funding to support these programmes. Relevant regulations, such as tax regimes, should be carefully examined and changed if needed to counteract the consequences of unemployment caused by AI-based automation.

119. Member States should encourage and support researchers to analyse the impact of AI systems on the local labour environment in order to anticipate future trends and challenges. These studies should have an interdisciplinary approach and investigate the impact of AI systems on economic, social and geographic sectors, as well as on human-robot interactions and human-human relationships, in order to advise on reskilling and redeployment best practices.

120. Member States should take appropriate steps to ensure competitive markets and consumer protection, considering possible measures and mechanisms at national, regional and international levels, to prevent abuse of dominant market positions, including by monopolies, in relation to AI systems throughout their life cycle, whether these are data, research, technology, or market. Member States should prevent the resulting inequalities, assess relevant markets and promote competitive markets. Due consideration should be given to LMICs, in particular LDCs, LLDCs and SIDS, which are more exposed and vulnerable to the possibility of abuses of market dominance as a result of a lack of infrastructure, human capacity and regulations, among other factors. AI actors developing AI systems in countries which have established or adopted ethical standards on AI should respect these standards when exporting these products, developing or applying their AI systems in countries where such standards may not exist, while respecting applicable international law and domestic legislation, standards and practices of these countries.

POLICY AREA 11: HEALTH AND SOCIAL WELL-BEING

121. Member States should endeavour to employ effective AI systems for improving human health and protecting the right to life, including mitigating disease outbreaks, while building and maintaining international solidarity to tackle global health risks and uncertainties, and ensure that their deployment of AI systems in health care be consistent with international law and their human rights law obligations. Member States should ensure that actors involved in health care AI systems take into consideration the importance of a patient's relationships with their family and with health care staff.

122. Member States should ensure that the development and deployment of AI systems related to health in general and mental health in particular, paying due attention to children and youth, is regulated to the effect that they are safe, effective, efficient, scientifically and medically proven and enable evidence-based innovation and medical progress. Moreover, in the related area of digital health interventions, Member States are strongly encouraged to actively involve patients and their representatives in all relevant steps of the development of the system.

123. Member States should pay particular attention in regulating prediction, detection and treatment solutions for health care in AI applications by:

(a) ensuring oversight to minimize and mitigate bias;

(b) ensuring that the professional, the patient, caregiver or service user is included as a "domain expert" in the team in all relevant steps when developing the algorithms;

(c) paying due attention to privacy because of the potential need for being medically monitored and ensuring that all relevant national and international data protection requirements are met;

(d) ensuring effective mechanisms so that those whose personal data is being analysed are aware of and provide informed consent for the use and analysis of their data, without preventing access to health care;

(e) ensuring the human care and final decision of diagnosis and treatment are taken always by humans while acknowledging that AI systems can also assist in their work;

(f) ensuring, where necessary, the review of AI systems by an ethical research committee prior to clinical use.

124. Member States should establish research on the effects and regulation of potential harms to mental health related to AI systems, such as higher degrees of depression, anxiety, social isolation, developing addiction, trafficking, radicalization and misinformation, among others.

125. Member States should develop guidelines for human-robot interactions and their impact on human-human relationships, based on research and directed at the future development of robots, and with special attention to the mental and physical health of human beings. Particular attention should be given to the use of robots in health care and the care for older persons and persons with disabilities, in education, and robots for

use by children, toy robots, chatbots and companion robots for children and adults. Furthermore, assistance of AI technologies should be applied to increase the safety and ergonomic use of robots, including in a human-robot working environment. Special attention should be paid to the possibility of using AI to manipulate and abuse human cognitive biases.

126. Member States should ensure that human-robot interactions comply with the same values and principles that apply to any other AI systems, including human rights and fundamental freedoms, the promotion of diversity, and the protection of vulnerable people or people in vulnerable situations. Ethical questions related to AI-powered systems for neurotechnologies and brain-computer interfaces should be considered in order to preserve human dignity and autonomy.

127. Member States should ensure that users can easily identify whether they are interacting with a living being, or with an AI system imitating human or animal characteristics, and can effectively refuse such interaction and request human intervention.

128. Member States should implement policies to raise awareness about the anthropomorphization of AI technologies and technologies that recognize and mimic human emotions, including in the language used to mention them, and assess the manifestations, ethical implications and possible limitations of such anthropomorphization, in particular in the context of robot-human interaction and especially when children are involved.

129. Member States should encourage and promote collaborative research into the effects of long-term interaction of people with AI systems, paying particular attention to the psychological and cognitive impact that these systems can have on children and young people. This should be done using multiple norms, principles, protocols, disciplinary approaches, and assessment of the modification of behaviours and habits, as well as careful evaluation of the downstream cultural and societal impacts. Furthermore, Member States should encourage research on the effect of AI technologies on health system performance and health outcomes.

130. Member States, as well as all stakeholders, should put in place mechanisms to meaningfully engage children and young people in conversations, debates and decision-making with regard to the impact of AI systems on their lives and futures.

V. MONITORING AND EVALUATION

131. Member States should, according to their specific conditions, governing structures and constitutional provisions, credibly and transparently monitor and evaluate policies, programmes and mechanisms related to ethics of AI, using a combination of quantitative and qualitative approaches. To support Member States, UNESCO can contribute by:

(a) developing a UNESCO methodology for Ethical Impact Assessment (EIA) of AI technologies based on rigorous scientific research and grounded in international human rights law, guidance for its implementation in all stages of the AI system life cycle, and capacity-building materials to support Member States' efforts to train government officials, policy-makers and other relevant AI actors on EIA methodology;

(b) developing a UNESCO readiness assessment methodology to assist Member States in identifying their status at specific moments of their readiness trajectory along a continuum of dimensions;

(c) developing a UNESCO methodology to evaluate ex ante and ex post the effectiveness and efficiency of the policies for AI ethics and incentives against defined objectives;

(d) strengthening the research- and evidence-based analysis of and reporting on policies regarding AI ethics;

(e) collecting and disseminating progress, innovations, research reports, scientific publications, data and statistics regarding policies for AI ethics, including through existing initiatives, to support sharing best practices and mutual learning, and to advance the implementation of this Recommendation.

132. Processes for monitoring and evaluation should ensure broad participation of all stakeholders, including, but not limited to, vulnerable people or people in vulnerable situations. Social, cultural and gender diversity should be ensured, with a view to improving learning processes and strengthening the connections between findings, decision-making, transparency and accountability for results.

133. In the interests of promoting best policies and practices related to ethics of AI, appropriate tools and indicators should be developed for assessing the effectiveness and efficiency thereof against agreed standards, priorities and targets, including specific targets for persons belonging to disadvantaged, marginalized populations, and vulnerable people or people in vulnerable situations, as well as the impact of AI systems at individual and societal levels. The monitoring and assessment of the impact of AI systems and related AI ethics policies and practices should be carried out continuously in a systematic way proportionate to the relevant risks. This should be based on internationally agreed frameworks and involve evaluations of private and public institutions, providers and programmes, including self-evaluations, as well as tracer studies and the development of sets of indicators. Data collection and processing should be conducted in accordance with international law, national legislation on data protection and data privacy, and the values and principles outlined in this Recommendation.

134. In particular, Member States may wish to consider possible mechanisms for monitoring and evaluation, such as an ethics commission, AI ethics observatory, repository covering human rights-compliant and ethical development of AI systems, or contributions to existing initiatives by addressing adherence to ethical principles across UNESCO's areas of competence, an experience-sharing mechanism, AI regulatory sandboxes, and an assessment guide for all AI actors to evaluate their adherence to policy recommendations mentioned in this document.

VI. UTILIZATION AND EXPLOITATION OF THE PRESENT RECOMMENDATION

135. Member States and all other stakeholders as identified in this Recommendation should respect, promote and protect the ethical values, principles and standards regarding AI that are identified in this Recommendation, and should take all feasible steps to give effect to its policy recommendations.

136. Member States should strive to extend and complement their own action in respect of this Recommendation, by cooperating with all relevant national and international governmental and non-governmental organizations, as well as transnational corporations and scientific organizations, whose activities fall within the scope and objectives of this Recommendation. The development of a UNESCO Ethical Impact Assessment methodology and the establishment of national commissions for the ethics of AI can be important instruments for this.

VII. PROMOTION OF THE PRESENT RECOMMENDATION

137. UNESCO has the vocation to be the principal United Nations agency to promote and disseminate this Recommendation, and accordingly will work in collaboration with other relevant United Nations entities, while respecting their mandate and avoiding duplication of work.

138. UNESCO, including its bodies, such as the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST), the International Bioethics Committee (IBC) and the Intergovernmental Bioethics Committee (IGBC), will also work in collaboration with other international, regional and sub-regional governmental and non-governmental organizations.

139. Even though, within UNESCO, the mandate to promote and protect falls within the authority of governments and intergovernmental bodies, civil society will be an important actor to advocate for the public sector's interests and therefore UNESCO needs to ensure and promote its legitimacy.

VIII. FINAL PROVISIONS

140. This Recommendation needs to be understood as a whole, and the foundational values and principles are to be understood as complementary and interrelated.

141. Nothing in this Recommendation may be interpreted as replacing, altering or otherwise prejudicing States' obligations or rights under international law, or as approval for any State, other political, economic or social actor, group or person to engage in any activity or perform any act contrary to human rights, fundamental freedoms, human dignity and concern for the environment and ecosystems, both living and non-living.



中小学阶段的人工智能课程

对政府认可人工智能课程的调研

ED-2022/FLI-ICT/K-12

2030年教育

UNESCO——全球教育领导机构

教育是联合国教科文组织工作的重中之重，它既是一项基本人权，也是建设和平和推动可持续发展的基础。教科文组织是主管教育的联合国专门机构，在全球和地区的教育领域发挥领导作用，以推动各国教育系统的发展，增强其韧性和能力，从而服务所有学习者。教科文组织通过变革性学习引领应对当今全球挑战的行动，并在所有业务领域重视性别平等和非洲。

2030年全球教育议程

教科文组织作为主管教育的联合国专门机构，负责领导并协调2030年教育议程——旨在通过17项可持续发展目标在2030年前消除贫穷的全球运动的一部分。教育既是实现各项可持续发展目标的关键，同时自身也是单独一项目标（可持续发展目标4），即“**确保包容和公平的优质教育，让全民终身享有学习机会**”。《2030年教育行动框架》为落实这一宏伟目标及各项承诺提供了指导方针。

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联合国教育、
科学及文化组织

2030年
教育

联合国教育、科学及文化组织，丰特努瓦广场7号，75352巴黎 07 SP，法国

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联合国教育、科学及文化组织2021

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中小学阶段的人工智能课程

对政府认可人工智能课程的调研

致 谢

本报告由联合国教科文组织教育信息化和教育人工智能部门制作，该部门隶属于未来学习和创新团队。

该部门负责人苗逢春负责数据收集方法的构思和执行，调查的设计和管理，并领导报告的撰写。JET 教育服务的 Kelly Shiohira 协助实施数据收集，分析调查数据，进行课程调研，并起草本了本报告。

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调研的目的和范围

人工智能技术已经成为了全球中小学的新学科领域，然而政府、学校和教师在定义人工智能能力和设计人工智能课程时依旧缺乏背景知识。本调研工作对现有的人工智能课程进行了分析，重点考察了人工智能课程的内容和学习结果，并探讨了其开发和验证机制、课程衔接，学习工具及所需环境的准备，教学法建议和教师培训。该研究分析得出了人工智能课程的重点考虑因素，以期能指导未来人工智能课程扶持性政策的规划、国家课程或机构研究项目的设计以及人工智能能力发展的实施战略。

调研的范围

教科文组织从全球视角出发，调查当前中小学教育中开发和实施人工智能课程的实践。本研究中的“人工智能课程”指的是人工智能相关主题的结构化学习项目：1)由国家或地区政府批准；2)对象为接受常规学校教育的幼儿园至 12 年级的学生。本研究不涵盖为职业技术教育与培训(TVET)机构、高等教育机构或非正式学习机会而设计的人工智能课程。

引言

目前，多种多样的人工智能技术正在全球范围内使用，人们愈发认识到人工智能在劳动市场中的重要性及其对日常生活的影响。人工智能将“影响各个收入水平和教育水平的职业”(Royal Society UK, 2018, cited in the Microsoft Computer Science Framework, 2021)。麦肯锡公司2018年的一项分析指出，到2030年，预计70%的全球企业将至少使用一种人工智能技术。然而，人工智能的使用会导致各国之间的现有差距逐步拉大 (Bughin et al. ，2018a)。目前在美国，机器承担了多达30%的劳动力任务 (Kelly, 2020)。此外，不断发展的自动化水平和人工智能集成水平也会导致学校、职业技术教育与培训机构中所教授的技能与就业市场所需技能愈发不匹配 (Bughin et al.，2018b)。新冠疫情加快了自动化的步伐，预计到2020年，会有多达1 / 16的工人需要接受再培训[1]，中、低技能工作所需的劳动力数量会进一步下降 (Lund et al., 2021)。

人工智能技术带来的影响并不局限于劳动力。它对文化、多样性、教育、科学知识、交流和信息都具有深远意义，特别是在涉及和平、可持续性、性别平等和非洲的具体挑战方面也影响颇深 (COMEST, 2019)。这些都是注重发展和政策的全球以及国家机构非常关注的领域。无论是有意为之还是潜移默化，人们与人工智能的互动在不断增加。人工智能目前已被应用于汽车驾驶、自动化客户服务、军事炸弹目标识别、国家入境口岸申请人员筛查、警务工作指导、分数评定、大学入学和奖学金选拔，以及个人财务决策 (Engler, 2021; Frantzman and Atherton, 2019; Shiohira, 2021)。

国际政策指南建议，应通过不同的情景化方法来寻求共同领域的发展，例如促进教育中人工智能的开放和公平使用；利用人工智能加强教育和学习；采用人工智能促进就业和生活技能开发；保护教育数据，使其运用合乎伦理、透明且可审计 (UNESCO，2019a)。然而，目前关注中小学人工智能课程的项目相对较少，这也促使政策制定者最近颁发了一项建议，即应该“为探索人工智能提供有利的政策环境和课程空间”(Miao et al. , 2021, p.34)。

教科文组织作为国际社会和教育信息化对话的主导力量，在教育领域的人工智能应用取得了一系列重要进展。

2015 年，《青岛宣言》(UNESCO, 2015) 提出了要探索大数据的潜力，提高网上学习效果，增强对学生行为和学习的理解，完善网络课程的设计和组织。该宣言敦促“各国政府必须制定政策并建立体系，确保包括学生个人身份信息等隐私和秘密的数据的使用安全、恰当、符合道德规范。”

- 《北京共识—人工智能与教育》(UNESCO, 2019b) 提出了一系列关于在教育领域应用人工智能的建议和考量。共识高度关注教育领域人工智能应用的公平和包容问题，提到要确保人工智能促进全民优质教育和学习机会，无论性别、残疾状况、社会和经济条件、民族或文化背景以及地理位置如何。
- 作为《教科文组织教育领域技术创新战略 (2022-2025)》的一部分，除了观察站和能力建设外，该组织还致力于制定准则性文书和开发规范性工具，包括制定框架和指导方针，以加强教师和学习者的数字化能力（认识、技能和价值观），并确保从终身学习的角度出发，以基于人权、安全、合乎伦理和

1 分析包含八个国家，即中国、法国、德国、印度、日本、西班牙、英国和美国，几乎占据全球一半的人口以及 62%的 GDP。

有意义的方式使用技术。”(UNESCO, 2021a)。横向行动领域的职能在于扩大受教育机会，尤其是针对边缘群体和个体提高教学和学习的质量。

- 教科文组织于2021年4月发布了《人工智能与教育：政策制定者指南》，旨在培养对人工智能做好准备的政策制定者 (Miao et al., 2021)。指南为目标读者阐释了人工智能的方向，包括机遇、风险、关键定义、人工智能的趋势、对教学的意义，以及教育如何使得学生做好准备迎接智能时代。指南在最后对地方的政策规划提出了建议。
- 2021年10月，教科文组织启动了人工智能与未来学习项目[2]，该项目包含三个各自独立但互为补充的部分：(1) 人工智能驱动的学习的未来相关建议报告；(2) 教育领域人工智能应用的伦理原则指南；(3) 在校学生人工智能能力指导框架。

当前人工智能的普遍应用及其对职场的影响激发了一种紧迫感，促使人们就人工智能应用的多方面达成了国际共识，包括：人工智能在社会中的可接受程度、人工智能在开发和部署中预期的人文因素考量，以及如何培养孩子们具备所需的能力，以使他们成功地驾驭现有的——而非未来的世界。《北京共识—人工智能与教育》(UNESCO, 2019b) 呼吁所有会员国都要“认识到进行有效的人机协作需要具备一系列人工智能素养，同时不能忽视对识字和算术等基本技能的需求”。该共识支持以一种“人文主义的方法”，“确保所有人具备在生活、学习和工作中进行有效人机合作以及可持续发展所需的相应价值观和技能。”。为支持《北京共识》的落实，教科文组织于 2020 年 12 月 7 日和 8 日举办了”国际人工智能与教育会议：培养新能力，迎接智能时代”。与会者认为：

> 世界公民需了解人工智能可能产生的影响，人工智能的功能和局限，人工智能何时有用，何时应该质疑其应用，以及如何引导人工智能为公众利益服务 (Miao and Holmes, 2021, p. 6)。

会议强调了以人为本能力的中心地位，如，对人工智能伦理及其社会影响的理解，以及技术导向的能力，（比如使用、解释和开发人工智能的技能和知识）。会议建议采用特定主题和跨学科的方法将人工智能应用于教育，包括在现有信息通信技术课程的基础上，将人工智能所带来的机遇和影响纳入人文、科学和艺术课程 (Miao and Holmes, 2021)。

本报告通过对政府认可的中小学人工智能课程及其设计、内容和实施的全球情况进行分析，进一步加深人们对人工智能在中小学教育领域应用的理解，帮助学生为在智能时代生活和工作做好准备。本报告旨在为支持性工具和框架的创建提供信息，以期能够制定人工智能能力的指导框架。本报告也是《教科文组织教育领域技术创新战略 (2022-2025)》(UNESCO, 2021a) 中所列工作的一部分。

人工智能技术术语和技术简介

本报告涉及来自人工智能专家和教育专业领域的一系列概念和术语。尽管人工智能在市场营销、金融乃至教育等领域无处不在，但部分决策者和从业者可能不熟悉本分析报告中使用的一些术语，也无法保证所有的人工智能从业者和决策者都了解人工智能课程教学法的应用趋势。因此，本节将简要介绍报告中讨论的一些技术、术语和教学方法，从而帮助读者建立对主要概念的总体理解。首先，本节将依次解释人工智能领域的五个术语，而后将在“教学法的概念和术语”章节介绍“基于能力的评价”、“建构主义（constructivism）”、“建构主义（constructionism）”和“设计思维”等几个概念。

2 详见 https://events.unesco.org/event?id=2883602288

几乎所有的概念和术语都引发了一定程度的学术辩论，辩论双方既有支持者也有反对者。但本报告的目的并非深入探讨这些冲突的观点，也不应将本报告视为对这些观点的详尽探索。

人工智能

“人工智能”一词始创于1956年， Marvin Minsky和 John McCarthy共同主持了当年的达特茅斯人工智能夏季研究项目(COMEST, 2019；Haenlein and Kaplan, 2019)。此后，随着大数据的兴起和计算能力的指数级增长，人工智能开始逐步普及 (Haenlein and Kaplan, 2019)，其定义也随着时间的推移不断扩展和演变 (Miao et al., 2021)。目前，人工智能特指模仿人类智慧（如感知、学习、推理、问题解决、语言互动和创造性工作）某些特征的机器 (COMEST, 2019)。

本报告将人工智能分为两类，即“人工智能底层技术”和“人工智能技术”。前者包括构建不同类型人工智能的方法，后者指的是研究领域和由这些技术创造出的产品。

人工智能底层技术

本报告分析的课程中所包含的人工智能底层技术可简要描述为:[3]

- **传统人工智能**是基于规则的，使用条件判断命令若-则 (if-then) 生成输出。基于规则的推理可以用于聊天机器人等技术(例如，“若输入包含‘什么’、‘价格’和‘？’的关键词，则能够返回产品价格列表”)。
- **机器学习(ML)** 是指可以通过访问和处理大量数据来“学习”，而无需依赖具体编程的计算机程序。这里的“学习”是指，与传统人工智能相比，程序无需被明确“告知”应该输出什么，即可生成新的输出。接下来介绍的技术属于机器学习的子类别。
- **有监督学习**属于机器学习的一种，它经过已知、标记的数据训练而生成输出。例如，**分类器**是一种算法，它使用已标记的数据将事物分类(例如“垃圾邮件”或“非垃圾邮件”)。**决策树**是一种分类算法，其中一系列的“节点”(决策点，即问题)指向“分支”，不同的回答选项会导向不同的分支。例如，在麻省理工学院的 DAILy 课程中，学生们通过创建决策树来对不同类型的意大利面进行分类。其中一个节点可能会问，‘是否超过 4 英寸?’，在此节点中，意大利面、意大利扁面条和其他长意大利面会被分配到同一分支上，从而指向下一节点，而通心粉、蝴蝶结面和其他短意大利面则会被分配到另一分支上。
- 在**无监督学习**中，机器学习是基于未知和未标记数据组中的相似度进行聚类而生成输出。
- **强化学习**是一种持续的机器学习，训练强化学习的目的是实现奖励最大化（例如，在投资上获得最大的货币回报）。
- **神经网络**是以动物大脑为模型的机器学习算法。它们由输入层、隐藏层和输出层组成。在隐藏层中，数据根据其值和分配的权重在节点中被处理，只有超过既定阈值的数据才得以通过。经过过滤的数据通过一个或多个隐藏层到达输出层。神经网络中的“学习”通过“反向传播”而实现，反向传播算法基于每个节点输入的正确性和影响，通过调整不同节点隐藏层中的权重来最小化误差。
- **深度学习(DL)** 是指具有多个隐藏层的神经网络。机器学习通常依赖于结构化的数据（例如选择、标记和表格化数据），而深度学习可以处理非结构化的数据，例如文本和图像。神经网络和/或深度学习常被应用于图像识别和语音识别。
- **生成式对抗网络(GANs)** 属于机器学习的一种，旨在生成新的内容，例如图像 [4]。一个生成式对抗网络包含两个深度神经网络。其中一个生成内容，另一个评估内容。生成式对抗网络目前还无法很好地处理文本。

3 此处的解释来自于 Miao et al. (2021)，且有本报告中包含的课程范例和定义做补充，尤其是麻省理工学院的 DAILy 课程、AI4K12 课程框架和 IBM 的青年挑战课程。

4 例如，生成式对抗网络技术可以用来生成虚拟人物图像 (详见 https://www.thispersondoesnotexist.com)。

人工智能技术

本调研分析的课程中所包含的人工智能技术可概述为：

- **聊天机器人**指的是用来模拟口头和/或书面对话的计算机程序。[5]
- **计算机视觉**属于人工智能领域，涉及从图像和视觉输入中获取和使用信息。计算机视觉驱动某些产品的制造，如自动化高光卷轴、自动驾驶汽车和质量控制工具（用于识别缺陷）。[6]
- **自然语言处理(NLP)** 基于计算机科学与计算语言学（研究人类语言的一个跨学科领域）的结合，旨在创建可被计算机使用，且基于规则的人类语音或文本模型，从而使计算机能够对人类语言加以处理并作出适当的反应。该技术驱动计算机完成不同语言间的翻译，以及卫星导航或数字助理等技术对口头命令的反应能力。
- **传感器**是用于测量某些物理特性（如温度或压力），并将数据传输到其他电子设备(如计算机处理器)的设施或系统。传感器是人工智能中收集数据的一种方法，是物联网 (IoT) 的基本组成部分。在物联网系统中，根据不同传感器的输入，无需人工干预即可采取行动 (Mahdavinejad et al.，2018)。比如物联网灌溉系统，该系统从嵌入在土壤中的传感器中收集信息，并以此来激活浇水设备。[7]

合乎伦理的人工智能

如前所述，人工智能应用广泛，好处良多。例如，人工智能在新冠疫情早期为人们提供了重要见解并发布预警。然而，人工智能的使用也引发了一系列伦理方面的考虑。使用的数据集和开发者的选择都可能导致人工智能引发偏见，引起歧视。由于某些类型的人工智能存在隐藏层等元素，人类无法直接看到、检查或纠正人工智能决策的过程以及其中的各类因素，因而会引发可解释性和透明度方面的问题。人工智能带来的其他挑战还包括在个人数据使用与个人隐私权之间的平衡；数据安全和潜在的网络犯罪风险；以及基于用户兴趣的人工智能算法对先入观念的强化可能会限制人们对某些观点和信息的接收，一些人认为，这会侵犯个体的言论自由权 (UNDESA et al., 2021)。

《人工智能伦理问题建议书》(UNESCO, 2020) 初稿强调了人工智能面临的一些关键伦理挑战，指出了人工智能对决策、就业和劳动、社会互动、医疗保健、教育、媒体、言论自由、信息获取、隐私、民主、歧视、武器开发等方面的影响。该建议书还提出，人工智能应由第三方监测，以确保其可信任性，使其能够服务于人类、个体、社会、自然环境及其生态系统。该建议书为人工智能伦理制定了 10 条原则:

1. **相称性和不损害**建议人工智能应该有合理的目标和目的，这些目标和目的应切合具体情况，并应建立在严格的科学基础之上。
2. **安全和安保**建议人工智能不应造成任何损害，且必须在其整个生命周期内防范人工智能的安全风险。
3. **公平和非歧视**建议人工智能系统应摒除偏见，并应在国家、地方和国际层面共享人工智能及其惠益，平等分配，不论“生理性别、社会性别、语言、宗教、政治或其他见解、 国家、民族、土著或社会出身、性取向、性别认同、财产、出生、残障情况、年龄或其他状况”如何。
4. **可持续性**建议在目标不断变化的背景下，应持续评估人工智能技术的社会、文化、经济和环境影响。
5. **隐私**建议以保护数据主体个人能动性的方式，进行人工智能的数据收集、使用、共享、存档和删除，并落实处理个人数据的“合法的目的”和“有效的法律基础”。

5 请见范例 https://towardsdatascience.com/building-a-chatbot-with-rasa-3f03ecc5b324
6 点击 https://www.ibm.com/topics/computer-vision，了解更多信息
7 请见范例 https://www.digiteum.com/iot-solutions-agricultural-irrigation-system

6. **人类的监督和决定**建议自然人或法人实体在伦理和法律上对人工智能负责。

7. **透明度和可解释性**建议，在根据人工智能算法作出决定时，人们有权知道。个人和社会实体可以要求获得并收到有关这些决策的解释，包括对细节因素和决策趋势的洞察。**可解释性**进一步要求："结果和导致结果的子过程应以可理解和可追溯为目标，并且应切合使用环境。"

8. **责任和问责**强化了人类监督与决策的原则，并建议应建立影响评估、监测和尽职调查机制，以确保对人工智能系统实施问责。同时必须保证人工智能的可审计性[8]。

9. **认识和素养**指的是政府、公共部门、学术界和民间社会有责任促进开放和可获取的教育以及其他以人工智能与人权交点为重点的举措，以确保"所有社会成员都能够就使用人工智能系统作出知情决定，避免受到不当影响"。

10. **多利益攸关方以及适应性治理和协作**建议各国应管理在其境内生成或经过其国境的数据；广泛的民间组织、公共和私营部门的利益攸关方应参与人工智能的整个运作周期；应采取措施，便于边缘化群体、社区和个人进行有效干预。

人工智能素养

在教科文组织人工智能与教育的未来国际论坛中发表的《人工智能时代的能力培养综合报告》(Miao and Holmes, 2020) 指出，世界公民需了解人工智能的潜在影响，人工智能的功能和局限，人工智能何时有用，何时应该质疑其应用，以及如何引导人工智能为公众利益服务。这需要每个人都具备一定程度的人工智能能力，包括知识、理解、技能和价值取向。综合而言，这些都可被统称为"人工智能素养"。人工智能素养包括数据素养，即了解人工智能如何对数据进行收集、清理、操作和分析的能力；以及算法素养，即理解人工智能算法如何在数据中找到可应用于人机交互的模式和联系的能力。针对该术语的解释是建构人工智能素养这一新兴领域范围、结构和主要类别的一次尝试，其使用已贯穿本报告中的研究。

教学法的概念和术语

"能力本位教育" (CBE) 是高等教育和职业技术教育与培训 (TVET) 经常追求的一种模式，但该模式正被越来越多地以各种形式应用于中小学教育。能力本位教育旨在将教育从原本的固定时间和灵活学习的模式转变为灵活时间和固定学习的模式。能力本位教育模式会通过评价来展现学生的应用知识、技能和价值观，并根据需求为学生提供尽可能多的额外支持，直到他们达到要求的基准 (NCLSorg, 2017)。

能力本位教育的核心概念是"能力"，该术语经过不断演变，现在主要用以描述对知识、技能、态度和价值观的动员，以满足日趋复杂的需求(OECD, 2019, p. 5)。课程的预期能力通常通过学生的学习结果或学生被期望在课程后了解、掌握的知识以及能够做到的事情来表现 (Biggs and Collis, 1982； Cedefop, 2017； Kinta, 2013)。"学习结果"是针对早期术语"学习目标"的修正，以确保强调的重点是学生——而非教师的行为或成就，并使用可测量的应用进行进一步定义 (Lopez et al., 2015； Sinha, 2020)。课程、学习结果和能力之间的关系在实践中比较复杂，但在理论上相当直接：课程描述了一系列预期的学习结果，评价则通过评估学生在特定研究领域或学科（最好是在新的领域）运用所学的知识、技能和态度/价值观来证明学生实现了这些结果——Biggs和Collis (1982) 的SOLO[9] 分类法将其称之为"拓展抽象 "的能力。

8 虽然建议中没有明确定义可审核性，但该术语指的是第三方访问、审查、监控和批评算法的能力 (Jobin et al., 2019)。
9 SOLO 代表"可观察的学习结果的结构（structure of observed learning outcome）"。

本报告的框架和审查的课程也参考了建构主义（constructivism）、建构主义（constructionism）、计算思维和设计思维。

“建构主义（constructivism）”是学术界的系列广泛概念，它适用于描述个体通过与他人，以及与自己的生理、文化和制度或系统环境的互动来创造或构建(有时是共同构建) 知识的方式 (Taber, 2016)。教育中应用的建构主义类别在很大程度上建立在 Piaget (1972) 的成果之上，他提出的理论概述了不同发展阶段的儿童能够获得和不能获得的学习类型及形式；例如，具体的应用会先于抽象。

与之相关的概念是“建构主义（constructionism）”，该理论认为，学生在将知识应用于个人感兴趣的项目中时获得的学习效果最好 (Papert and Harel, 1991)。建构主义尤其适用于数字课程，原因在于，它一方面起源于信息通信技术和数学领域，另一方面，它专注于意义产生的方式，即，意义通过参与、操纵和改变数字人工产品的过程产生 (Kynigos, 2015)。尽管建构主义（constructivism）者和建构主义（constructionism）者的基础相同，但是后者挑战的是 Piaget（1972）列出的知识层次结构，认为学生可以通过使用数字媒体和基于块的编程等方法，在早年有效地处理更为复杂的概念 (Papert, 1996)。

计算思维，即为一个问题构建数字解决方案而引发的一系列心理和生理过程(确定一个问题，将其分解为多个部分，构建和吸收解决方案，而后测试并提炼它们)。计算思维在理论上适用于计算机科学之外的系列领域(Lodi and Martini, 2021)。计算思维的四个“部分”可被称为分解、抽象、分析和算法 (Kush，2019)。Lee et al. (2011) 研究了中小学阶段学生的一系列计算思维活动，并确定其过程确实可以被不同人口统计学背景的学生所运用。他们进一步提出了一种“使用-修改-创造”的学习进程模型用于参与计算思维，并指出熟练的教师、发展考虑和适当的技术是计算思维的关键支持机制。

在本报告中包含的部分课程背景介绍中，最后一个要提的工具是“设计思维”。它被定义为“一个使个体有机会进行实验、创建和制作原型模型，收集反馈，并进行再设计的分析和创造过程”(Razzouk and Shute, 2012)。设计思维最初出现于考古学、市场营销和经济学等领域 (Buchanan, 1992)，20世纪90年代初开始在工业中应用，并发展为一种以消费者为导向来设计创新产品或商业模式的方法，特别是与技术相关的产品或模式 (Hobcraft, 2017)。设计思维的过程包括共情（如与消费者共情），定义问题，产生解决方案，然后在迭代设计循环中进行原型化和测试，直至实现理想化的创新 (Hasso Plattner Institute of design, 2010)。在学校，设计思维可以为学生提供一个清晰的程序，以应对数字化以及跨学科活动和相关能力对他们提出的要求。

现有人工智能课程参考框架

最近出现了几项旨在规划或建立中小学阶段人工智能课程框架的举措。本节将详细介绍其中的三个框架：“人工智能素养：能力和设计的主要考虑因素”，“AI4K12: 中小学阶段人工智能指南”[10] 和“机器学习教育框架”。这并非一份详尽的清单，因为许多非政府组织、行业、学术组织和/或个人已经开发了用以支持自身项目和事业的人工智能课程框架。政府也在使用其中的一些框架，如微软的计算机科学框架，这些都将在稍后的学习结果调研情况中呈现。本节讲述的三个框架是为系列合作伙伴的人工智能课程开发提供信息，与特定的产品或课程无关。

10 详见 https://ai4k12.org

人工智能素养：能力和设计的主要考虑因素

Long and Magerko (2020) 基于对现有研究进行的范围研究 (Scoping Study) 提出了一系列有关人工智能素养的能力和设计考虑因素，旨在确定以下新兴主题：1)人工智能专家认为非技术受众应当了解的知识，2)学习者的普遍认知和误解。

他们的范围研究提出了17项能力和13项设计考虑因素。描述显示，“能力”普遍处于知识分类的较低层次，主要局限在理解、描述和识别。由Long和 Magerko 提出的“能力”相关描述见**表1**。

表 1. 人工智能素养能力框架

能力	描述/ 学习结果
1. 人工智能识别	区分使用和未使用人工智能的技术产品。
2. 对智能的理解	对一个实体“人工智能”的特征进行批判性地分析和讨论。探讨人类智慧、动物智慧与机器智能之间的区别。
3. 跨学科性	认识到思考和开发“智能”机器的方式有很多。认识应用人工智能的各种技术，包括跨认知系统、机器人和机器学习技术。
4. 广义人工智能vs狭义人工智能	区分广义的人工智能和狭义的人工智能。
5.人工智能的优缺点	确定人工智能擅长/不擅长的问题类型。明确何时适合使用人工智能，何时适合利用人类技能。
6.未来人工智能畅想	畅想人工智能未来的潜在应用方式，并考虑这些应用方式对世界的影响。
7. 表征	理解什么是知识表征，并能描述一些知识表征的例子。
8. 决策	识别并举例描述计算机是如何进行推理和决策的。
9. 机器学习步骤	理解机器学习所涉及的步骤，以及每一步所需的实践和遇到的挑战。
10. 人类在人工智能中扮演的角色	认识到人类在编程、选择模型和调试人工智能系统中发挥的重要作用。
11. 数据素养	理解基本的数据素养概念。
12. 数据学习	认识到计算机经常从数据（包括自身的数据）中学习。
13. 批判性数据解读	理解数据需要被解读。描述在初始数据集中提供的训练示例是如何影响算法结果的。
14. 行动与反应	理解有些人工智能系统能够在现实世界中做出行动。这种行动可能会由更高层次的推理（如沿着计划好的路径行走）或反应性冲动（如向后跳以避开感觉到的障碍物）指导。
15. 传感器	理解什么是传感器，以及计算机通过使用传感器感知世界。识别各类设备上的传感器。理解有关世界不同类别的表征和推理由不同的传感器支持。
16. 伦理	识别并描述围绕人工智能关键伦理问题的不同视角：隐私、就业、错误信息、“奇点”、[11]决策、多样性、偏见、透明度和问责制。
17. 可编程性	了解代理是可编程的。

来源: Long and Magerko, 2020

Long and Magerko (2020) 提出的设计考虑因素重点关注教学法和学习方法，同时也考虑了社会和人际关系因素。总体而言，他们强调体验式学习和材料的相关性，赞成认知需求和儿童发展理论，以及人工智能在学习者学习环境中的定位。两位研究者提出了 15 项具体的主要考虑因素:

1. **可解释性：**包括图形可视化、模拟、对代理决策过程的解释，或交互式演示，以帮助学习者理解人工智能。

11 描述了人工智能变得比人类更聪明时的情景，与此同时也引发了人工智能可能会有意伤害人类的担忧。

2. **具身交互：**设计个体可以充当或跟随代理的干预措施，从而理解代理的推理过程。这可能涉及算法的具体模拟和/或使用人工智能技术进行实际实验。

3. **情景化数据：**鼓励学习者调查谁创建了数据集，如何收集数据，以及数据集的局限性。这可能涉及到选择与学习者生活相关、低维且“混乱”的数据集（如未清洗或分类不整齐的数据集）。

4. **提高透明度：**提高人工智能设计各方面的透明度（例如，消除黑箱功能，共享创建者意图、资金/数据来源等）。

5. **分层教学：**为防止认知超负荷，用户可选择查看和了解不同的系统组件；一次只针对几个部分进行解释；或者进行支架式教学，随着用户对系统操作的了解增加，再逐渐移除支架。

6. **提供编程机会：**为个人提供编程和/或教授人工智能代理的方法。通过专注于视觉/听觉元素与/或结合类似于 Parsons problems 编程工具和代码填空等策略，将编码先决条件降至最低。

7. **考虑发展关键期：**考虑发展的关键期（如心理发展理论）、年龄和先前技术经验对人工智能认知的影响。

8. **批判性思维：**通过质疑人工智能应用的智能性和可信度，鼓励学习者做人工智能技术的批判性消费者。

9. **考虑身份、价值观和背景的影响：**考虑学习者的身份、价值观和背景如何影响他们对人工智能的兴趣和先入之见。结合个人身份或文化价值观的学习干预可以对他们的兴趣和动机起到激励作用。

10. **为家长提供支持：**当面向家庭进行设计人工智能时，考虑帮助家长构建孩子的人工智能学习体验。

11. **社会交互：**设计有助于社会交互和协作的人工智能学习体验。

12. **激发学习者的兴趣：**在设计人工智能素养的干预措施时，可利用当前的问题、日常体验或游戏、音乐等常见的消遣方式。

13. **确认先入观念：**承认学习者可能会从流行媒体中建立对人工智能的政治化或情绪化的先入观念，并考虑如何在学习干预中尊重、处理和引申这些观念。

14. **新视角：**引入在流行媒体中被忽略的视角（如宣传较少的人工智能子领域，针对人工智能产生的危险和益处展开的公平讨论）。

15. **低入门门槛：**考虑如何向缺乏数学或计算机科学背景的学习者传达人工智能概念（例如，减少先决知识/技能的传授，将人工智能与先验知识联系起来，并解决学习者对自身能力不自信的问题）。

AI4K12：五个基本概念与中小学阶段人工智能课程指南

AI4K12 计划由美国人工智能协会 (AAAI)、计算机科学教师协会 (CSTA) 和 AI4Al 1于2018年联合发起，旨在为中小学阶段的学生教授人工智能课程制定国家级指导方针 (AAAI, 2018)。

该团队汇集学者、研究人员和教师，致力于开发以五个基本概念为基础的综合人工智能框架，五个基本概念为：1)计算机通过传感器感知世界；2)代理维护世界表征，并利用它们进行推理；3)计算机可以从数据中学习；4)智能代理需要多种知识才能与人类自然地互动； 5）最核心的是，人工智能既可以以积极的方式作用于社会，也可以对社会产生消极影响。如今，“人工智能的五个基本概念”的相关海报已被译作15种语言12，并在一定程度上为人工智能课程在多元环境下的开发奠定了基础，包括本研究涵盖的多门课程。

工作组召开会议将这些概念逐个分解，最终形成一个课程框架，该框架面向 2 年级、3 到 5 年级、6 到 8 年级以及 9 年级到高中 3 年级划分为四个部分。到目前为止，前三个概念的课程纲要已经起草完成，正在面向公众征询意见。[13]

12 详见 https://ai4k12.org/resources/big-ideas-poster
13 详见 https://ai4k12.org/gradeband-progression-charts

在课程纲要中，每个“基本概念”被划分为不同的学习概念，这些学习概念又被进一步细分为不同的概念构成要素。例如，**表2**总结了“基本概念1:知觉”的学习概念、概念构成要素和相关学习结果。

表 2. “基本概念 1：知觉”的学习概念、概念构成要素和学习结果

学习概念	概念构成要素	学习结果进程
感觉	生物	2年级：识别人的感觉和感觉器官。 3-5年级：比较人类和动物的感知能力。 6-8年级：举例说明人类如何组合多形式来源的信息。 9年级-高中3年级：N/A
	计算机传感器	2年级：找到并识别计算机（摄像头、麦克风）、手机、机器人和其他设备上的传感器。 3-5年级：说明计算机传感与人类传感的区别。 6-8年级：举例说明智能代理如何组合来自多个传感器的信息。 9年级-高中3年级：描述各类计算机传感器的局限和优点。
	数字编码	2年级：N/A 3-5年级：解释图像是如何在计算机中以数字形式呈现的。 6-8年级：解释声音是如何在计算机中以数字形式呈现的。 9年级-高中3年级：解释雷达、激光雷达、GPS和加速计的数据是如何呈现的。
处理	感觉vs知觉	2年级：举出智能机器和非智能机器的例子，讨论是什么让机器变得智能。 3-5年级：通过使用软件工具，如语音转录或物体视觉识别的示例来展示机器知觉，并解释为什么这是知觉而不仅仅是感觉。 6-8年级：举例说明可以从传感信号中提取意义的不同类型的计算机感知。 9年级-高中3年级：解释感知算法及其在现实世界中的应用。
	特征提取	2年级：举例说明，如果想在一幅图像中识别某一类物体或实体(如猫)，应该寻找哪些特征。 3-5年级：通过提取面部特征来演示人脸检测的工作原理。 6-8年级：通过模拟边缘检测器来阐述从图像中进行特征提取的概念。 9年级-高中3年级：解释从波形和图像中提取特征的工作原理。
	抽象管道：语言	2年级：描述组成口语的不同声音，针对每个元音，列举出一个包含该音节的单词。 3-5年级：举例说明在部分声音并不清晰的情况下，是如何将一系列声音识别为单词的。 6-8年级：说明在部分单词并不清楚的情况下，单词序列是如何被识别为短语的。 9年级-高中3年级：从波形到句子，说明语音理解的抽象层次。
	抽象管道：视觉	2年级: 通过识别图像中的前景和背景来演示前景/背景分割。 3-5年级：说明图像中部分被遮蔽（挡住）物体的轮廓与其完整形状的区别。 6-8年级：描述如何将边缘检测器组合成更复杂的特征检测器，例如字母或形状。 9年级-高中3年级：展示较高抽象层次的知觉推理是如何借鉴早期、更低抽象层次的推理的。
领域知识	领域知识种类	2年级：描述智能代理必须“知道”才能理解某个问题的例子。 3-5年级：展示文语转换系统是如何利用上下文来解决歧义的，以及错误率是如何随着不符合语法的输入而增加的。 6-8年级：将给定的图像分类，并描述计算机需要什么样的知识才能理解该类型的场景。 9年级-高中3年级：对一个或多个在线图像数据集进行分析。描述数据集所提供的信息以及如何利用这些信息提取计算机视觉系统的领域知识。
	包容性	2年级：探讨为什么智能代理需要理解其他语言。 3-5年级：探讨如何确保领域知识的广泛性以适用于应用服务的所有群体。 6-8年级：描述当视觉系统对某些客体缺乏了解，而这些客体又不存在于已创建的文化当中，视觉系统会表现出怎样的文化偏见。 9年级-高中3年级：描述阻碍计算机感知系统针对不同群体正常运作的技术困难。

来源: AI4K12 (2020)

每个基本概念都被以类似的方式进行分解，从小学早期到高中，都有一个具体的学习结果路径。除了以上学习结果之外，课程纲要还列出了学生期望保留的“持久知识”的例子，例如:“声音通过对离散点波形采样（通常以每秒几千个样本的速度）的方式进行数字编码，从而产生一系列的数字”，或“口

语的层次结构为：波形➡ 发音姿势➡ 声音➡ 语素➡ 单词➡ 短语➡ 句子”。有时，学习结果和持久知识会被进一步分解，正如第二个例子所示:“从嘈杂、模糊的信号到有意义的信号，需要在多个抽象层次上识别结构并应用领域知识。”举一个经典的例子:“如何识别语音”和“如何破坏一个美丽的海滩”两句话在波形水平上几乎完全相同。

在学习中，建议可偶尔进行一些活动。例如，若要为3-5年级的学生解释决策树，“猜动物”游戏(”guess the animal” game)，故障解决(troubleshooting problems)和Pasta Land活动值得推荐。

几大基本概念之间是相辅相成的。例如，“基本概念3”利用传感部件的知识，深化了针对人与计算机学习方式差异的讨论。同样，它以部件处理的知识为基础，使得学习者具备标记机器学习数据集，训练分类器，以及使用包括决策树、神经网络、有监督学习、无监督学习和强化学习等在内的人工智能概念的能力。

机器学习教育框架

尽管机器学习教育框架 (Lao, 2020) 从未提及能力本位教育 (CBE)，但它遵循了著名的CBE知识、技能和态度框架（在其他背景中该框架还包含能力和/或价值观等要素)(Brewer and Comyn, 2015; CANTA, 2014; European Parliament and Council of the European Union, 2006)。由于缺乏对学生任务意义的关注以及对能力持简化主义观点，能力本位教育在过去曾一度受到批评。尽管这种观点广泛根植于绩效的背景之下，但其过于忽视个体因素，比如先前的经验和利用外部资源的灵活性－如团队成员的知识 (Rutayuga, 2014)。然而，建构主义（constructivism）和经验学习等理论的逐渐整合 (Brunner, 1990; Kolb, 2015; Piaget, 1972; Williams, 2017) 促成了能力本位框架的形成，该框架注重“头、心和手”的融合发展，其中“头”代表认知领域（你所了解的有关它的知识），“心”代表情感领域（它为什么重要）以及“手”代表精神运动领域（你可以用它做什么）(Gazibara, 2013；Williams, 2015； SiposWilliams，2008)。理论的整合同时扩展了能力的概念，增加了社交和情感两种技能 (European Parliament and Council of the European Union, 2006; Mulder, 2007)。

除此之外, Lao (2020) 借鉴了:

- 建构主义（constructionism），即通过建构对学生有个人意义的项目可以促进学习的理念；
- 计算思维，对熟悉的能力概念进行重构，具体应用于编程世界：技术概念、编程实践以及个人与技术关系的观点；
- 理解计算思维课程学习结果的模型，它分为抽象概念，也就是将概念应用到新用例的能力；自动化，即利用计算机提高重复工作的效率；以及分析，即对学生提出的假设及实施方法的反思 (Lee et al., 2011)。
- 使用-修改-创造 (UMC)，一种经常在计算思维课程中使用的分层递进方法。在课程中，学生先了解现有的软件，然后根据新需求修改软件，最后开发新的软件 (Lee et al.， 2011)。

机器学习教育框架（如**表3**所示）包含六门“机器学习公民必修课程”，课程主要受众为“进修者/消费者”(Lao, 2020, p.61)。在该框架中，Lao认为理解人工智能的偏见和社会影响是针对所有技能获取的基本要求。

表 3. 机器学习教育框架-学习结果和定义

知识	
1. 关于机器学习的通用知识*	了解什么是机器学习（以及什么不是机器学习）。理解创造机器学习系统的整个流程。
2. 关于机器学习方法的知识	明确何时在全领域应用机器学习的系列方法（例如，k近邻算法、CARTs或决策树、神经网络、集成方法)。了解不同方法的工作原理。
3. 机器学习的系统偏见*	了解系统可能存在偏见，且偏见产生的层次和方式可能不尽相同。
4. 人工智能的社会影响*	了解机器学习系统可以产生广泛的积极和消极影响，考虑其带来的的伦理、文化和社会影响。
技能	
1. 机器学习问题范畴界定	明确哪些问题可以且应该采用机器学习来解决。
2. 机器学习项目规划	规划一个对技术和具体情景兼具敏感性的解决方案。
3. 机器学习产品开发	使用工具开发合适的产品。
4. 机器学习设计交互和结果分析*	描述机器学习系统的显式和隐式设计意图。批判性地分析系统能够及应该如何服务于该意图。
5. 机器学习评价*	批判性地讨论机器学习政策、产品和教育。
6. 独立的课外学习	学生们在课堂外寻求学习经验。
态度	
1. 兴趣	学生愿意参与并有兴趣研究该主题。
2. 身份认同和社群合作	学生在机器学习社群和/或更广泛的在线社区中做出贡献并从中学习。
3. 自我效能感	学生们有权创造新的、有意义的东西。
4. 持续学习	学生保持并扩大对机器学习的参与度。

**星号代表框架中列出的六门必修课程。*

来源: Lao, 2020

针对这一框架，Lao(2020) 还提出了根据该框架评估机器学习项目的规则，建立了出口级的标准基础，并可以此为标准进一步建立规则。例如，“知识”项下的四种学习结果中，得分最高的是：

1. **关于机器学习的通用知识：**完成本课程学习的学生能够给出机器学习的精确定义、机器学习管道步骤的详细说明，并能充分考虑每个步骤的技术和社会伦理因素。
2. **关于机器学习方法的知识：**完成本课程学习的学生能够准确地辨别何时使用全领域的机器学习方法。他们能够描述这些方法的核心技术概念，并在适当的应用中熟练使用/实现它们。(Lao 随后阐述了相关观点，涉及不同教育阶段应采用的适当方法：
   - **高中及以上：**k 近邻算法、CART/DT、回归分析、卷积神经网络； 无监督方法，如 k-均值聚类、主成分分析、生成式对抗网络和嵌入(Embedding); RNNs / LSTMs; 强化学习; 迁移学习以及集成学习算法。
   - **中小学：**启用相关应用，使学生利用机器学习完成特定任务，例如利用神经网络和生成式对抗网络的相关应用创造艺术或音乐作品，或者将强化学习应用到游戏当中等等。）
3. **偏见：**完成本课程学习的学生能够描述机器学习系统如何在其管道的每个步骤中对特定群体产生不可预测的偏见。他们可以在自身工作中批判性地融入伦理思维和设计的实践。
4. **社会影响：**完成本课程的学生能够意识到，对于机器学习技术的创造者来说，考虑其工作带来的社会影响是相当有必要的。他们能够从伦理和文化的视角、概念出发，全面、关联且敏感地分析机器学习的产品（即考虑隐私、安全、滥用的可能性，以及利益和损害的平衡；并使用利益相关者分析、伦理矩阵和模型卡等工具评估民族志的接受程度和不同影响）。

研究方法

数据收集

本研究包含两次调查，第一次调查主要针对193个教科文组织会员国代表开展，第二次调查覆盖了10,000多个私营部门和第三方机构人员[14]。调查要求调查对象报告常规中小学教育阶段中学生的人工智能课程。附录A是分发给各会员国代表的调查问卷。分发给私营部门和第三方机构人员的问卷在此基础上做了细微调整。

问卷收集后，对于那些回答了本国在某一发展阶段设置了人工智能课程的调查对象，研究团队通过电子邮件向他们进一步询问了有关学习结果、课程实施和准备情况的问题。

此外，团队还与会员国代表、非营利领导人、开发商、学者和行业专业人士开展了半结构化的知情人访谈，以进一步了解这些课程及其在学校的设置情况。访谈讨论了各方人工智能课程的开发动机，以及他们围绕实施方法和教学法做出决定时的考虑因素。

最后，研究人员对那些已起草或出版且可供审查的课程开展了调研。调研工作主要关注每个课程中列出的学习结果。同时也尽可能地审查了相关教科书或材料，以进一步了解课程所涵盖的内容。

政府认可的人工智能课程选择标准

本研究主要关注政府认可的常规中小学课程。研究结果仅涵盖已经或正在被国家、地方政府批准的人工智能课程。如前所述，本研究中的“人工智能课程”是指涵盖人工智能领域的主题并结合人工智能相关学习结果的结构化学习项目。

通过教科文组织官方通信渠道联系的193个会员国中，共有51个会员国回应表示对这一项目感兴趣。其中29个国家和一个地区完成了全面的调查。

- 来自10个国家的代表报告称自己的国家没有开展人工智能课程。这些国家是：巴林、加拿大、哥伦比亚、哥斯达黎加、爱沙尼亚、几内亚、马其顿、马尔代夫、新加坡和乌克兰。
- 来自20个国家和一个地区的代表回应称，据他们了解，本国至少有一门已经政府开发、认可，或正在开发的人工智能课程。这些国家是：阿尔及利亚、亚美尼亚、奥地利、比利时、加拿大（育空地区）、法国、德国、约旦、韩国、科威特、老挝、秘鲁、葡萄牙、卡塔尔、保加利亚、沙特阿拉伯、塞尔维亚、斯洛文尼亚、叙利亚和阿拉伯联合酋长国。

此外，共有31家非政府组织、学界和行业合作伙伴对此次非政府调查做出了回应，称自身开设了人工智能课程。

对于那些报告开展了人工智能课程的会员国，研究人员已通过邮件与他们取得联系，以沟通后续问题，并要求他们提供可用的课程文件。

在邮件跟进和课程调研的过程中，我们发现一些报告的课程不符合本研究的严格标准。如果一项课程中不包含针对人工智能的学习结果，没有涵盖常规中小学教育（例如，侧重于职业技术教育与培训），没有得到国家或地区政府的认可，和/或没有提供足够的可供分析的信息，那么该课程将被排除在进一步的分析之外。

14 这些人员来自教科文组织在 2011 年至 2020 年组织的 9 次移动学习周期间累积的教育信息化领域的重要组织名单。

政府认可的人工智能课程列表

在调查的课程中，由政府机构或在政府机构的指示下开发的课程属于“政府”课程。只有那些在调查和访谈中提供了明确、一致且有意义资料的课程才能被纳入后续的分析当中。

将选择标准应用于所有的政府和非政府调查数据后发现：

- 共有11个会员国开发、认可和实施了人工智能课程。
- 加拿大育空地区开发并实施了一门名为“应用设计、技能与科技”的课程，该课程获得了区域，而非国家的认可。

表 4. 政府认可并实施的中小学阶段人工智能课程

国家/ 地区	课程名称	课程开发者[15]	受教育水平		
			小学	初中	高中
亚美尼亚	信息通信技术课程	政府		X	X
奥地利	数据科学和人工智能	联邦教育、科学和研究部			X
比利时	信息技术数据库	瓦隆-布鲁塞尔联合会 （比利时法语区）			X
中国	信息科技课程中的人工智能课程	中华人民共和国教育部	X	X	X
印度	Atal Tinker 实验室人工智能模块	Atal Tinker 实验室，Atal 创新计划，印度国家转型研究所 (NITIAayoag)		X	X
韩国	高中数学学科群下设的“人工智能数学”课程	韩国科学与创意振兴基金会			X
	高中技术家庭经济学科群下设的“人工智能基础”课程	韩国科学与创意振兴基金会			X
科威特	标准课程	课程的技术指导专家和教师	X	X	
葡萄牙	信息和通信技术	州立学校的信息通信技术老师与数学教师	X	X	X
卡塔尔	计算和信息技术	Binary Logic，教育与高等教育部	X	X	X
	计算和信息技术（高科技方向）	Binary Logic，教育与高等教育部			X
塞尔维亚	信息学和编程- 8年级	教育部工作组		X	
	艺体课程中的现代技术-3-4年级	教育部工作组			X
阿拉伯联合酋长国	纳入技术学科框架的人工智能课程	教育部	X	X	X

来源: UNESCO (2021b)

除了正在实施的课程之外，本研究还分析了那些处于开发过程中，且可能得到政府机构认可的课程。如**表5**所示，这些课程包括来自塞尔维亚的三门人工智能课程，以及来自德国、约旦、保加利亚共和国和沙特阿拉伯的各一门课程。

15 本列显示了在已完成调查中调查对象给出的回答。

表 5. 政府组织开发中的中小学阶段人工智能课程

国家/ 地区	课程名称	课程开发者	受教育水平		
			小学	初中	高中
德国	1. 识别和表述算法	联邦州教育部和文化事务部常务会议	X	X	X
约旦	2. 数字技能	国家课程发展中心		X	X
保加利亚	3. 计算建模、信息技术和信息学	专家组(由学术界、教师、教育专家构成)	X	X	X
沙特阿拉伯	4. 数字技能	Binary Logic 和 Tatweer Co.公司	X	X	X
塞尔维亚	5. 底层技术与应用科技	教育局工作组		X	
	6. 艺体课程中的人工智能	教育局工作组			X
	7. 面向所有高中的人工智能课程	教育局工作组			X

来源: UNESCO (2021b)

如果“非政府”课程包括了人工智能的学习结果，并至少与一个地方政府在任一实施阶段进行合作，则可将这些课程纳入研究。然而，这些课程尚未得到政府机构的正式认可，而只是满足了非政府课程的选择基准。

部分开发人员参与了与所列课程有关的其他工作，这些工作也纳入了课程调研的审查。其中包括 “IBM-CBSE 面向11和12年级的人工智能”的课程修订工作，以及微软开发的“人工智能、数据分析和机器学习”系列教材，二者都是为印度学习者设计；此外还有“微软计算机科学课程工具包”。

表 6. 本研究中作为基准的非政府人工智能课程

国家/ 地区	课程名称	课程开发者	受教育水平		
			小学	初中	高中
国际	1. IBM教育技术青年挑战	IBM		X	X
	2.人工智能青年技能	微软		X	X
	3.全球人工智能预备课程(高科技方向)	英特尔		X	X
	4.全球人工智能预备课程(普通方向)	英特尔		X	X
美国	5. DAILy 课程	麻省理工学院		X	X

来源: UNESCO (2021b)

本调查分析的局限性

如前所述，本调查分析并未涵盖与发展学龄儿童人工智能能力相关的所有内容，甚至也没有涵盖与政府人工智能课程相关的所有可用信息。仍有大量课程不在本报告的研究范围之内。例如，奥地利提交了三门课程，但有两门是在职业技术教育与培训部门开设的，因此不纳入本研究。一些营利性机构提供了有关专有技术的培训，许多人工智能培训项目由非政府组织通过非正式的学习渠道提供，如独立学习，以上这些都未被列入本研究的分析范围。

其他局限性包括：

- **缺失部分政府认可的人工智能课程。**调查已发送给193个会员国，但部分开设人工智能课程的国家可能没有作出答复。
- **数据有漏洞。**许多课程中没有找到调查所需的数据，特别是有关学校和学习者数量的数据，这些课程要么没有追踪这些数据，要么没有得到数据的授权，因此无法公布。
- **未来的相关性有待考证。**受时间限制，此次调研涉及到的许多课程仍在开发中，可能还会被进一步修订。此数据集仅反映非政府和私营部门活动的大致情形，其未来用途可能有较大局限。

政府认可的人工智能课程分析：主要结果

分析结果由以下五个部分组成：

1. **课程开发和认可机制**讨论了人工智能课程的授权、动机和认可方法。
2. **课程整合与管理**涵盖了将人工智能课程纳入教育系统的方法，如何按百分比和总学时进行时间分配，以及为支持人工智能课程而准备的必要条件。
3. **课程内容**概述了三个主要课程领域的内容中，不同专题领域的时间分配。三个课程领域分别是：人工智能基础；伦理和社交影响；理解、应用和开发人工智能工具。
4. 该部分介绍了经过调研的人工智能课程**学习结果**，该部分的学习结果从知识、技能和价值观三个能力领域定义。
5. **课程实施**总结了以下三方面的主要策略，包括：教师培训与支持、必要学习工具和学习环境的准备，教学法建议。

课程开发和认可

如上文所列，11个国家的政府机构认可并授权学校开展14门人工智能课程，与此同时，还有5个国家的7门人工智能课程尚在开发中。其中仅塞尔维亚既有已获认证的课程，也有仍在开发的课程。此外，另有两门课程受到了地方政府的认可，分别是：加拿大育空地区的应用设计、技能与科技课程，以及美国麻省理工学院的DAILy课程。在部分分析当中，四个私营部门和非政府部门的人工智能课程也被列为基准。

人工智能课程的开发和认可机制

- **政府集中指导的方法**

这些课程大多是由国家公共机构开发的，并通过政府集中指导的办法授予认可。有时，主要利益攸关方也会参与课程的开发或者与国家公共机构合作开发。例如，韩国的人工智能课程开发工作就是由业界专家在政府的指导下开展的；在中国、科威特和保加利亚共和国，教师，学者和专家也会参与人工智能课程的开发工作。

- **政府委托私营部门提供课程服务**

第二种方法是由政府委托私营部门提供课程服务。在沙特阿拉伯和卡塔尔，政府会委托企业开发国家课程。来自沙特阿拉伯的代表称：

> 由于技术日新月异，应用的功能频繁更新，我们选择与一家高质量的私营公司合作，这家公司在信息通信技术课程开发、最新技术与 IT 应用融合方面声名显著。

- **政府指导，权力下放的方法**

第三种方法是在政府的指导下，将权力下放。在比利时，议会授权制定标准，然后由学校采用并确定要使用的技术和教学方法等。德国也采取了类似的做法，地方或省级政府在国家授权和相关标准的基础上做进一步开发，再将其纳入学校实施的课程。

- **非政府性的私营部门开发的人工智能课程**

最后，部分人工智能课程是由非政府性的私营部门推动开发的。当私营部门为政府机构开发课程时，学校可以直接采用，或者交由当地专家进行修订。这些课程需具备一定的灵活性，从而适用于各类政府框架及要求，或者课程会根据具体国情进行进一步的定制。课程开发和认可的一个重要步骤是在国内和国际条件下进行验证。英特尔的代表评论道：

> 我们的课程得到了各国的广泛认可……我们在国际上创建了一个可以为课程提供评估验证的专家库，我们向专家提供需要修改和建议的内容。专家库在 2019 年和 2020 年开始实施，期间做了大量的评估工作。

但没有证据表明，私营部门推动的人工智能课程获得了政府的认可。采用该方法开发课程的私营部门，包括IBM、英特尔、微软和麻省理工学院在内的行业或学术利益攸关方在咨询专家和教师后，都开发了自己的课程和资源。

人工智能课程开发的愿景和动机

调查对象指出了开发人工智能课程的两个重要原因：提高能力以应对劳动力市场的技能需求，以及确保学生毕业时能够掌握社会和政治生活中进行日常互动所需的技能。然而，这些考虑因素的受重视程度完全不同。例如，有些国家表示它们根本不关心劳动力市场的技能需求，而另一些国家则将其视为主要的考虑因素。

首先，为劳动力市场培养技能的目标反映了技术部门和更广泛工作领域不断变化的需求。对大多数（但不是所有）国家来说，这与培养具有国际竞争力的劳动力愿景息息相关。企业开发人员提到，这是他们将人工智能培训课程的开发纳入企业社会责任活动当中的强大动机。

第二个原因与对人工智能作为社会和经济转型驱动力的理解有关，同时也与为学生培养有关人工智能及其在社会中的功能和用途的通用知识的愿望有关。几位调查对象指出，人工智能已经扎根于一系列日常人际互动中，他们认为公民有能力在所处的环境中识别人工智能，了解其益处和潜在的挑战，并有权倡导安全、有益和透明的人工智能技术。来自葡萄牙、奥地利和约旦的代表的评论证明了这一点：

> 对于技术对未来的影响，我们有一个清晰的认识，我们需要能够在日常生活中以健康的方式使用技术的劳动力和民众。这就需要通过概念、意识和技能等来改善这些方面，实现人机合作，同时将机器人视为社会服务的补充。这是我们的总体愿景。
>
> 人工智能被视为一个广泛的议题，它具有颠覆性的潜力来改变生活中的关键领域和概念。因此，当我们考虑到人工智能在教育中的应用时，除了专家和开发者，使所有人具备对人工智能基本知识的了解同样非常重要，因为这些基础知识可以帮助他们在智能的世界中安全、自主地生活。
>
> 我们的计划是开发一套数字技能课程，它既能够适应全球的发展和预期的数字化转型，同时也能够帮助我们获得适宜的全球性数字能力。

人工智能课程的试用和评估

以下提到的政府人工智能课程已经过实施和评估，包括：保加利亚共和国的计算建模、信息技术和信息学课程；中国的信息科技课程；麻省理工学院的DAILy课程；塞尔维亚的信息学和编程课程、现代技术课程和底层技术与应用科技课程；以及阿联酋实施的技术学科框架。

此外，以下非政府人工智能课程的实施也通过了评估，包括：IBM的教育技术青年挑战；英特尔两个版本的青年人工智能：全球人工智能预备项目，以及微软的人工智能青年技能。

部分课程根据评估结果进行了修改，包括中国、阿联酋、IBM、英特尔（两个版本）、微软和麻省理工的人工智能课程。还有一些课程仍处于试用阶段，可能会接受进一步修订，比如保加利亚的一项课程、麻省理工学院的DAILy课程和塞尔维亚的底层技术与应用科技课程。

常见的评估方法包括：

- **专家评审课程。**例如，在阿联酋，会将人工智能课程与不同的社会利益攸关者共享，包括学者和人工智能专家。心理学和教育学专家也会进行跨学科审查。
- **开发者实施的课程研究。**研究方法包括对学习者开展测试，对教师、地区和/或国家行政部门的代表进行采访和调查；此外，还会收集有关学习结果、课程实用性和实施的挑战等信息。
- **外部评估。**一些政府委托外部机构对课程和/或学习结果进行评估。例如，保加利亚共和国委托外部机构开展了一项全国性评估，致力于衡量学习者的数字能力。

这些审查或评估很少对外公布。 采访中发现的一个关键点在于：人工智能课程应该与数学课程和课堂要求相协调。例如，中国的一项课程审查发现，信息科技课程的科目要求水平高于数学和科学科目的要求水平，因此需要对课程预期作相应调整。此外，课程还必须适应广泛的背景，考虑到城市和农村环境的独特机遇和挑战。

在有关麻省理工学院 DAILy 课程的一项试点研究中，老师们发现学生们似乎比平时上课时更加投入。而学生理解课程的关键问题是：“什么是人工智能，什么不是人工智能”。部分老师认为，与伦理相关的课程模块莫名其妙且令人困惑，但有些老师却欣然接受。硬件的使用被视为是课程试用过程中最难管理的部分，尽管使用硬件能够帮助学生培养重要的技能，如弹性能力，但当设备无法正常工作时，往往需要教师施以大量的投入和关注 (Williams et al，2021)。

示例：卡塔尔课程开发的基础和原则 [16]

卡塔尔2030国家愿景[17]认为科技是现代知识型经济社会的一个重要元素，卡塔尔国家课程框架 (QNCF) 将信息技术列为1-12年级的主要学习科目，旨在“为孩子们的学习提供有益的机会，包括在逻辑和数学思维、语言和交流、读写萌发和创造力培养方面”。

为支持这些国家政策，行业专家、卡塔尔教育和高等教育部的信息通信技术专家团队，以及小学、预科和中学的信息通信技术主管通力合作，制定了国家计算机和信息技术课程基础标准。卡塔尔三所高等教育机构的计算机科学专家与课程开发专家一起对该标准进行了审查。依据该标准开发的课程包括所有年级的必修课程和高中阶段的选修课程（“高科技方向”）。这两种方向的课程均涵盖与算法和编程、伦理和社交影响相关的人工智能学习结果，以及对人工智能工具和技术的理解与应用。选修高科技方向课程的学生也将学习人工智能的产品开发。

卡塔尔旨在定期审查这些标准，以确保它们符合计算机科学和信息技术领域最新的技术成果和发展趋势。同时，为保证标准的可持续性，需确保课程不依赖于特定的技术、平台或应用程序。此外，为提高标准的有效性，课程框架还建议将教师反馈和关于国际最佳实践的审查结合起来另做调整。

卡塔尔的计算和信息技术课程标准的开发遵循以下五项主要原则：

1. 与国家课程框架保持一致。包括“能力、价值观、目标、原则和跨领域问题”，确保能力的培养与国家标准挂钩。课程涵盖知识、技能和态度三个维度，重点关注：

16 本节中的信息来自卡塔尔教育和高等教育部编制的《2018 年卡塔尔计算和信息技术课程》。可通过电子邮件询问获取。

17 详见 https://www.gco.gov.qa/en/about-qatar/national-vision2030

- 计算机科学原理和实践，即编程、机器人和人工智能；
- 数字素养，在课程中的定义为“以创造性和高效的方式来使用和应用计算机系统”，包括伦理、知识产权和电子安全等方面；
- 软技能的提升，根据美国学校图书馆管员协会的定义，软技能包括：协作、沟通、团队合作、批判性思维、解决问题和决策。

2. 螺旋式的发展。螺旋式的发展使得各种概念知识在不同年级多次出现，并随着每一次的迭代不断提高其难度和深度。与此同时，技能的发展必须连贯且有效，以避免不必要的重复和学术差距。
3. 以学生为中心的学习和基于实践项目的方法。计算思维是其中的核心要素，旨在使学生能够利用抽象、自动化和分析的过程作为解决问题的新方法，从而帮助他们在一年级阶段理解计算思维的基本原理。
4. 计算语言、硬件和平台的独立性。这意味着课程不需要依赖特定的供应商、品牌或编程语言，而可以涵盖学生在现实生活中遇到的广泛工具和技术。

课程整合与管理

人工智能课程可以通过多种方式被整合至现有的教育系统：

- **独立人工智能课程。**该类型课程是在国家或地方课程框架内开发的独立学科类别。这些课程有自己的时间分配、教材和资源，如，中国面向高中1-2年级设置的信息科技课程下设的人工智能基础课程。

- **归入式的人工智能课程。**该类课程在国家或地方课程框架下的其他学科类别中开发，并被纳入其中。人工智能不仅是信息通信技术或计算机科学中最常见的主题，也是语言、数学、科学或工程学科的一部分（见**图1**）。韩国已经开发了两门人工智能选修课程，其中一门隶属于数学学科群，另一门被纳入技术家庭经济学科群。人工智能课程也可以根据教师的能力和兴趣，灵活地归入任何学科。麻省理工学院的DAILy课程就属于此种情况。

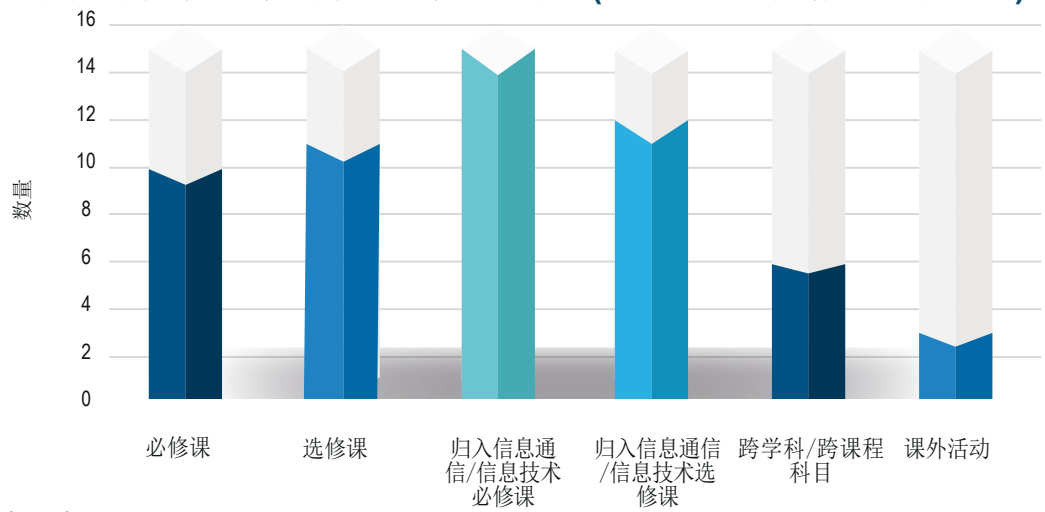
- **跨学科人工智能课程。**此类课程往往在对跨学科工作和时间有特殊要求的系统中实施。这些课程旨在通过涵盖多学科领域的基于项目的学习，实现人工智能的学习结果。以葡萄牙的人工智能课程框架为例，其特点是“自主课程领域”，或项目必须涉及两到三个学科的跨学科方法。在阿联酋，人工智能被整合到包括信息通信技术、科学、数学、语言、社会研究和品德教育等在内的一系列学科当中。

- **多课程方式相结合的人工智能课程。**该类课程的核心要求在于：不仅需要在开学期间实施，且需要传统教学资源的支持（如教师指导和教材），同时也需利用校外资源网络和国家或国际竞赛等非正式的学习机会。此类课程的代表是“IBM-CBSE 面向11和12年级的人工智能课程”，该课程结合竞赛和行业指导，帮助学生实现从引导式学习到独立学习的逐步过渡。

- **弹性人工智能课程。**此类课程可根据地区、学校网络或个别学校的实际情况，通过一个或多个整合机制实施课程。例如，印度的ATL人工智能模块课程，可通过归入其他课程、跨学科合作或与课外活动结合等校外模式实施；沙特阿拉伯的数字技能课程，可作为独立或归入式的课程实施。还有部分课程的归入机制取决于地区、学校或网络。这类课程包括比利时法语区的信息技术数据库（二、三级技术过渡），以及德国的识别和表述算法课程。

课程可以采用必修课模式，即所有学生均须参加；或者采用选修课模式，由学生自主选择是否参与。在一些课程中，比如中国的信息科技课程，有些模块属于必修课，有些则是选修课。

图 1. 人工智能课程数量–按课程整合类型划分 (n = 27，可能存在多项选择)



*来源：*UNESCO (2021b)

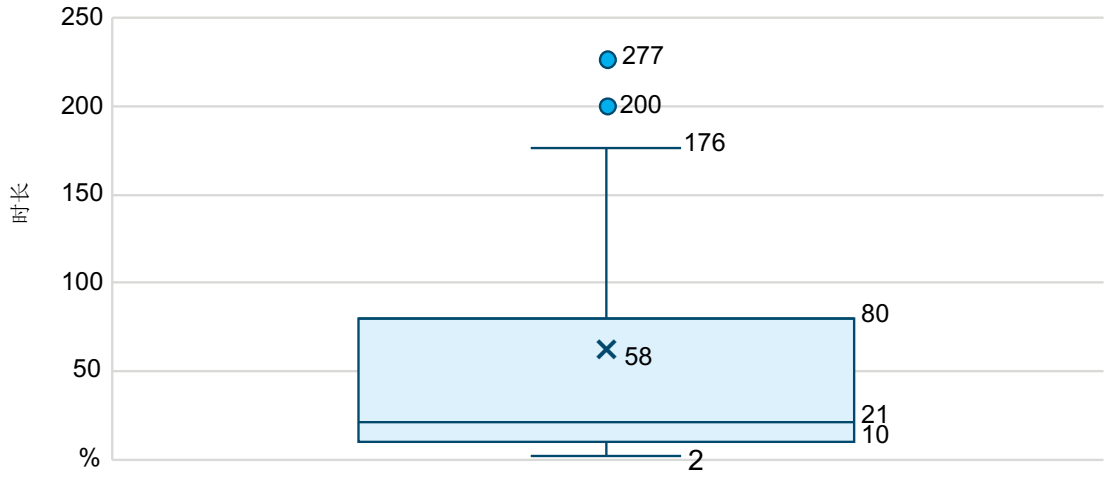
一个重要观点在于，人工智能课程以及更广泛的信息通信技术课程不应严重依赖于某一种特定的技术，因为在不同平台和供应商中开发多样化的技能是非常重要的。奥地利和中国等一些国家强调对技术采取“不可知法”，这意味着课程不与任何特定品牌、设备或编程语言挂钩。因此，这些课程旨在确保(i)教师培训牢固扎根于理论的基础之上，教师理解可应用于一系列技术的基本原则；(ii)如果使用特定的硬件或软件，教师和学习者将被引入多种选择，并与不同的人工智能工具供应商接触。

人工智能课程的课时分配

要求调查对象提供四个学段中每个年级的学习时长，包括：小学早期（覆盖1-2年级）；小学后期（涵盖3年级至小学毕业）；初中（覆盖大多数国家的7-9年级）；以及高中（涵盖大多数国家的10-12年级）。

从1年级到12年级，课程分配的总时长从2小时到924小时不等，各年级时间投入的箱线图[18](见**图2**) 表明，课时分配存在较大差异。

图 2.人工智能课程每年的课时分配情况，n = 22



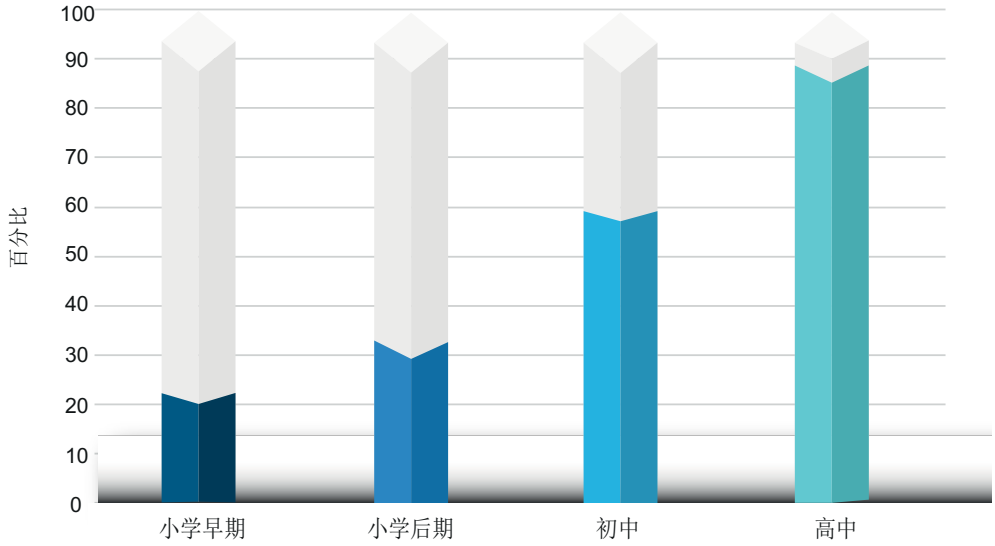
来源:UNESCO (2021b)

由图可见，存在两个异常值—卡塔尔的计算和信息技术（高科技方向）课程和比利时的信息技术数据库课程，这两门课程每年的平均课时分配超过200小时。图中均值为58小时，是中位数21小时的两倍多。这表明，部分课程在人工智能领域设置的课时较少。事实上，在提供了课时分配的22门课程中，有5门要求其每年人工智能课程学习时长少于5小时，另外有5门课程要求其人工智能课程学习时长超过150小时。要求150小时以上课时分配的课程要么是行业发展课程（5门课程中的2门），要么是高科技选修课（5门课程中的2门）。而分配课时较少的人工智能课程都被归入了其他科目。

课程最倾向于面向高中生开设。从小学早期到高年级，人工智能课程所占比重随着教育水平的提高而稳步增加（见**图3**）。

18 箱线图显示了数据的分布情况，包括最小值、第一四分位数、中位数、第三四分位数和最大值。平均值显示为“X”，箱线图上方的点为异常值。

图 3.各学段的人工智能课程占比(n = 27)



来源: UNESCO (2021b)

各学段人工智能课程的总课时分配在1到680小时不等。在1-2年级，人工智能最有可能被合并到其他科目中，且没有规定特定的课时分配。只有卡塔尔的计算和信息技术课程专门为1-2年级分配了100小时的人工智能课时。据报告，3-6年级学生的人工智能课程平均课时为156个小时。总体而言，初中（7-9年级）的人工智能课程平均课时为109小时，高中（高中1-3年级）的人工智能课程平均课时为153.5小时。1-9年级的人工智能课程平均课时相对稳定：1-2年级为33.3小时；3-6年级为39小时；7-9年级为36.3小时。在高中，各年级人工智能课程的平均课时增加到了51.2小时。

支持人工智能课程的必要条件

调查对象被问及，为确保人工智能课程的设计和实施获得支持，做了何种规划和准备。**表7**列出了调查中的七个应答选项，可多项选择，也可开放回答。

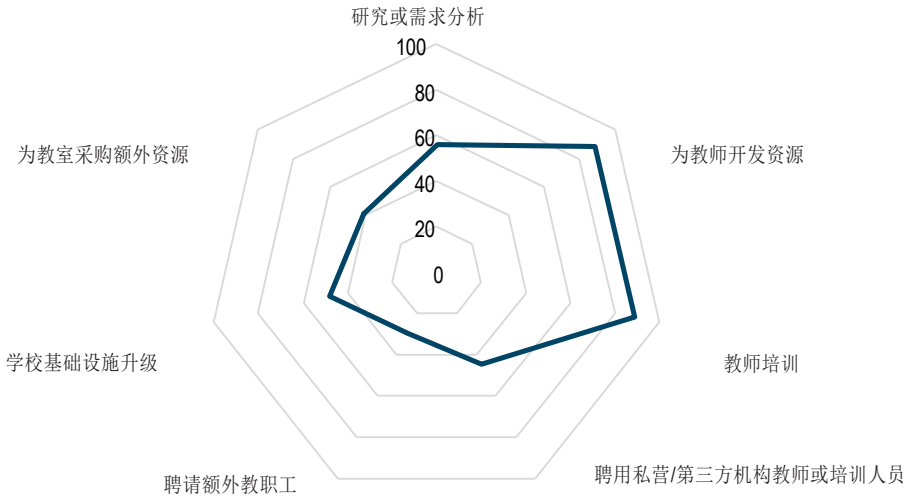
表 7.支持人工智能课程的必要条件

应答选项	注释
研究或需求分析	仅指与课程实施相关的研究或需求分析。
为教师开发资源	如，教科书和教案。
教师培训	调查对象被问及人工智能课程相关的具体培训和培训资源。
新增工作人员/职位的聘用	指有偿聘用更多教师授课。
私营或第三方机构参与	一些国家聘请私营或第三方机构组织成员，而非额外的学校工作人员（或者除额外的学校工作人员之外）作为学校的兼职培训人员，。
学校基础设施升级	指为学校提供与人工智能课程有关的硬件和/或网络连接。包括计算机室和服务器等。
为学校或教室采购额外资源	购买课堂工具包、编码资源、人工智能工具等。

来源: UNESCO (2021b)

调查统计显示，实施人工智能课程需要对教育系统的资源和人员能力进行一系列的统筹和调整（见**图4**）。大多数人工智能课程(89%)选择通过为教师开发资源和培训的方式获得支持；15门课程(56%)选择通过初步研究或需求分析获得支持；13门课程(48%)选择改善学校基础设施；12门课程(44%)报告通过私营或第三方机构参与的方式支持课程的实施；11门课程(41%)选择为教室采购额外资源。聘用额外的工作人员授课是几种方式中最不受重视的部分，仅有8门课程(30%)报告采用了此种方式支持课程的实施，但其存在仍然不容忽视。

图 4. 为课程实施提供的支持



来源: UNESCO (2021b)

示例：印度中等教育中央委员会引入人工智能课程 [19]

2019年，印度中等教育中央委员会(CBSE)宣布在其管辖的2.2万多所学校内开设人工智能课程，作为一门选修课，目的是确保印度未来的公民能够了解人工智能，并能够应用人工智能解决本地和全球性的问题。该课程侧重于“在做中学”，使学生有机会使用人工智能解决社区挑战，从中学习人工智能(CBSE, 2020)。

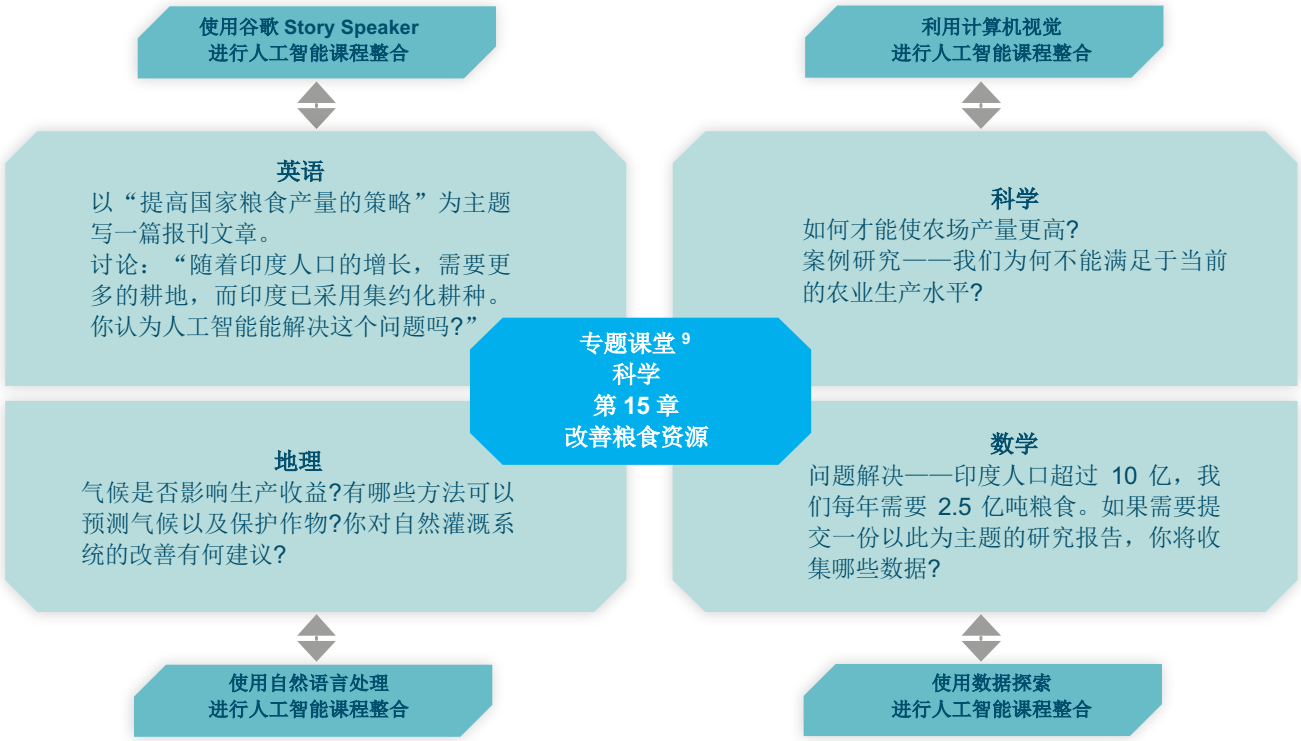
为了支持课程的实施，印度中等教育中央委员会与IBM、英特尔和微软等行业供应商合作，共同开发培训、支持性材料和内容。非政府组织也为课程的实施提供了支持。[20] 与此同时，他们安排了教师和导师培训，并编制了一系列材料，包括针对8年级到高中3年级的辅导员指南、多学科教案和教材。印度中等教育中央委员会还开展了一系列活动，旨在“使人工智能顺利地融入学校”。这些活动包括竞赛、虚拟研讨会，致力于为年轻人探索人工智能技术提供更多机会。系列活动还还包括为期三天的“AI-thon”夏令营，学生们可利用人工智能执行项目设计和原型循环，以应对特定的社区挑战。种种类似的合作活动已经吸引了超过1万名教师和12万名学生接受人工智能方面的培训。

自主安排人工智能课程设置的学校将课程作为选修课或跨学科课程进行整合。印度中等教育中央委员会邀请所有学校参加这一课程，学校管理人员也应向印度中等教育中央委员会提交申请，以响应这一号召。在此之后，学校选择教师进行培训，并计划将人工智能课程纳入学校课表，根据常见专题（如**图5**中的示例“改善粮食资源”）围绕人工智能的跨学科整合制定战略(CBSE and Intel, 2019)。

19 资料来源:印度中等教育中央委员会人工智能(Ministry of Education，India, 2020)；人工智能课程，9 年级辅导员手册(CBSE 和 Intel, 2019)；以及对 IBM、英特尔、1M1B 基金会和微软代表的采访及介绍。请注意，此信息可能不代表印度政府的官方观点。

20 例如，1M1B 基金会与印度中等教育中央委员会及 IBM 合作，以支持人工智能青年技能课程的实施。详见 https://www.youtube.com/watch?v=wKl5pghClFY

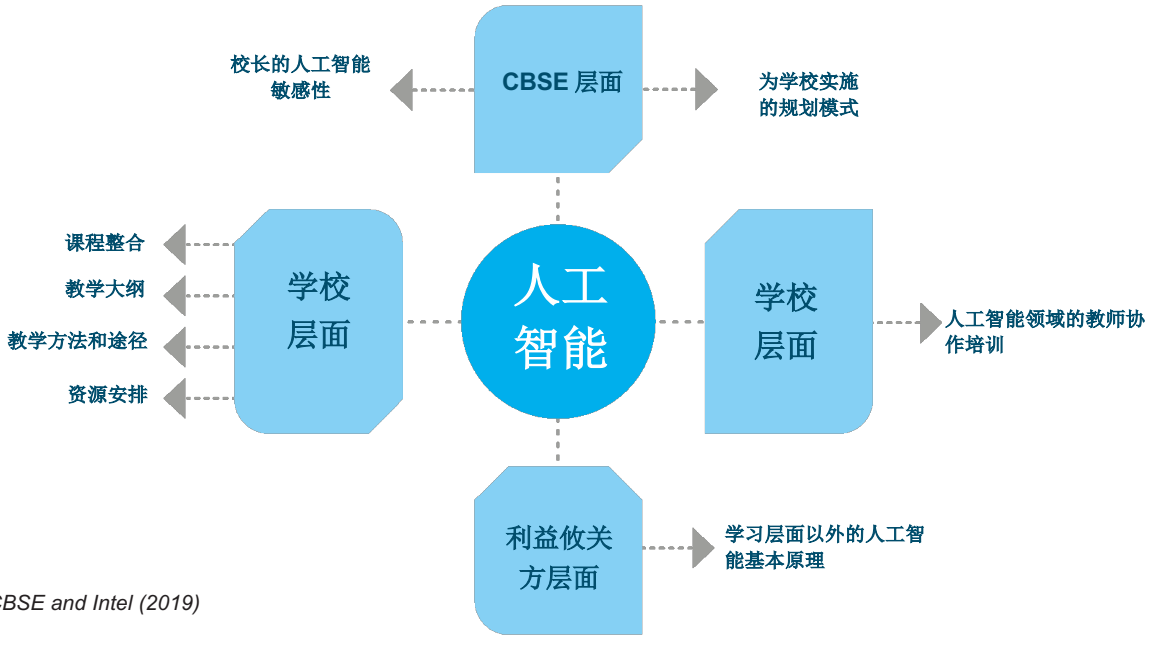
图 5. 人工智能课程跨学科整合的专题方法



来源: CBSE and Intel (2019)

在学校层面，行业和/或执行伙伴使用定制的课程和资料推动教师培训的开展。各类供应商，如IBM和微软，已经编写了符合印度中等教育中央委员会课程目标的教科书。课程整合、教学大纲、教学方法、教学途径和必要资源的采购也会在院校层面进行管理。此外，学校还希望使利益攸关方，尤其是学生和家长参与进来，以确保他们理解将人工智能课程整合的原因和目标。**图6**概述了印度中等教育中央委员会、学校和利益攸关方之间的关系。

图 6.人工智能课程实施的参与者和过程



来源: CBSE and Intel (2019)

人工智能课程内容

人工智能课程内容的主要类别

本分析涵盖了人工智能课程的九个专题领域：算法与编程；数据素养；情景化问题解决；人工智能伦理；人工智能的社会影响；人工智能在其他领域的应用；理解和应用人工智能底层技术；理解和应用人工智能技术；以及开发人工智能应用程序。

如**表8**所示，这九个专题领域被归为三个课程领域：人工智能基础；伦理和社交影响；理解、应用和开发人工智能。研究人员要求调查对象提供了关于以上专题领域的课时和课程占比相关信息，如**表9**所示。

表 8. 人工智能课程领域

课程领域	专题领域	能力和课程考虑因素
人工智能基础	算法与编程	算法和编程，以及数据素养，被视为应用人工智能技术的基础。
	数据素养	大多数人工智能应用均在“大数据”的基础上运行。从数据收集到清理、标记、分析和报告，针对整个数据周期的管理组成了使用和/或开发人工智能的技术基础之一。对数据及其功能的理解也有助于学生了解为什么人工智能会带来伦理和战略上的挑战，以及它在社会中发挥了什么样的作用。
	情景化问题解决	人工智能通常被视为商业或社会挑战的潜在解决方案。在此层面上，需要一个合乎具体情境的问题解决框架，包括设计思维和基于项目的学习等。
伦理和社交影响	人工智能伦理	撇开专业技术不谈，未来社会的学生将在个人和职业生活中与人工智能打交道——许多人从很小的时候就开始了。对于每个公民而言，理解人工智能所带来的伦理挑战非常重要，其中包括：什么是“合乎伦理的人工智能”；有关人工智能的透明、可审计和合理使用等概念；以及在不正当或非法情况下使用人工智能（例如包含有害偏见或侵犯隐私权的情况）的补救途径。
	人工智能的社交或社会影响	从要求调整法律责任框架到激励劳动力转型,人工智能的社会影响范围甚广。调查对象被问及其课程在多大程度上针对这些问题。其中以劳动力转移、法律框架变更和新治理机制的建立等为例。
	除信息通信技术外，人工智能在其他领域的应用	人工智能在计算机科学之外的领域也有广泛的应用。调查对象被问及是否考虑了人工智能在其他领域的应用，以及考虑的程度。其中以艺术、音乐、社会研究、科学和健康为例。
理解、应用和开发人工智能	理解和应用人工智能底层技术	该领域包括：(1)针对人工智能过程理论理解的发展程度（例如，定义或演示不同模式，或标记机器学习模型的不同部分）；(2)学生使用现有的人工智能算法生成输出的程度（例如训练分类器）。以机器学习、有监督学习和无监督学习、强化学习、深度学习和神经网络等人工智能底层技术为例。
	理解和应用人工智能技术	人工智能技术通常是面向人类的应用程序，可看作是一种“提供的服务“。以自然语言处理和计算机视觉为例，调查对象会被问及学习者在多大程度上使用现有的人工智能技术完成任务或项目，以及/或对这些技术的开发过程进行研究。
	开发人工智能应用程序	开发人工智能应用程序涉及开发新的人工智能应用程序，这些应用程序可解决社会挑战或提供新型服务。这是一个需要系列复杂技术知识以及编码、数学（尤其是统计学）、数据科学技能的专业领域。

来源: UNESCO (2021b)

人工智能课程分领域的课时分配

必须指出的是，关于人工智能课程范围的定义存在一定程度的模糊性。特别是在将人工智能归入信息通信技术课程的国家，调查对象可能不会将数据素养或算法和编程纳入人工智能课程内容的一部分，因为他们认为这是信息通信技术课程的一部分，由于有些人工智能课程并不能涵盖与人工智能相关的所有方面，这也影响了调查对象有关课时分配的回答。因此，对于调查对象而言，对本节的回答应被解释为课程或课程组成部分中的人工智能相关内容。

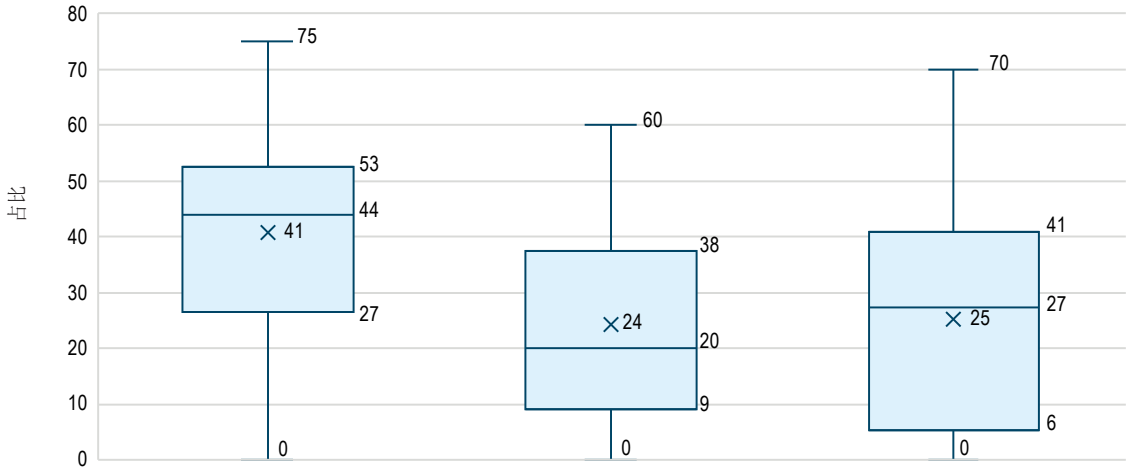
对于政府主导的课程，官方代表根据他们对课程和教育制度的了解，对课时分配占比进行了估算。而由于课时分配或科目整合方面的决策权下放，部分调查对象无法估计课程占比。此外，对于IBM、英特尔、微软和麻省理工学院等的部分课程，课时占比由研究人员根据课程内容计算得出，而非由调查对象估算得出 。

最后，并非所有课程占比相加就能达到100%，也并非所有国家都给出了针对课程的解释说明，或在后续调查中提交了回应上述挑战的补充信息。

人工智能课程分领域的覆盖范围

“人工智能基础”课程领域包括算法与编程、数据素养和情景化问题解决，它构成了大多数人工智能课程的基础，平均占据41%的课程时间。其余课时几乎由“伦理和社交影响”（ 平均占比24%），以及“理解、应用和开发人工智能” （平均占比25%）课程领域均分。**图7**对三个课程领域进行了比较。

图 7.主要课程领域课时占比箱线图 [21] （n=21）



来源: UNESCO (2021b)

如果以小时数而非百分比计算总投入课时，可以清楚地看到，目前“人工智能基础”占据了最大的课时份额。在“伦理和社交影响”领域的课时投入增加了三倍多，在“理解、应用和开发人工智能”领域的课时投入也增加了两倍多（见**表9**）。

表 9.课程参与度-按专题领域划分

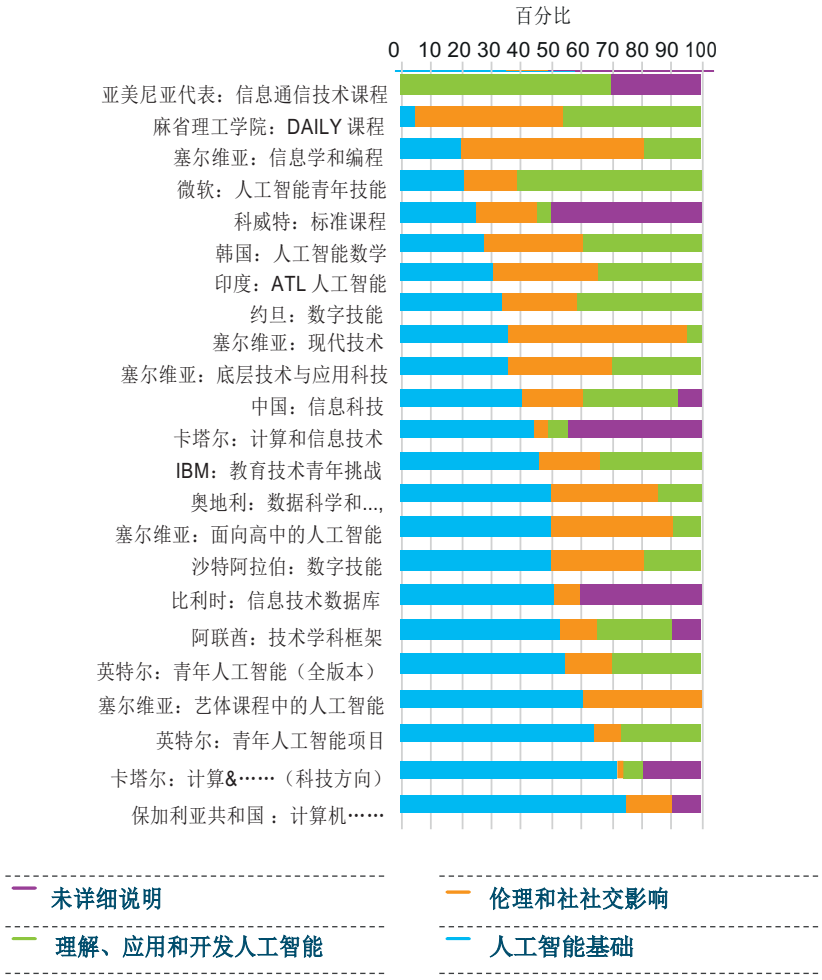
	人工智能基础	伦理和社交影响	理解、应用和开发人工智能
涵盖专题领域的课程数量 (n = 21)	20	20	18
课时范围	0–432	0–185	0–465
平均课时投入 （总计）	99.8	29.7	39.0
平均课时投入 （有课时安排的课程）	104.8	31.2	45.5
课时投入中位数 （有课时安排的课程）	31.3	13.7	11.9

来源: UNESCO (2021b)

21 来自韩国的一门人工智能课程，以及来自加拿大育空地区课程的课时占比未被报告。

根据**图8**中的课程分布和**表8**中的课程范围可以看出，人工智能课程的重点各不相同。“人工智能基础”领域的课时分配占比从0到75%不等；“伦理和社交影响”领域占比从0到60%不等；“理解、应用和开发人工智能”占比从0到70%不等。

图 8. 课时分配-按专题领域划分 (n = 23)



来源: UNESCO (2021b)

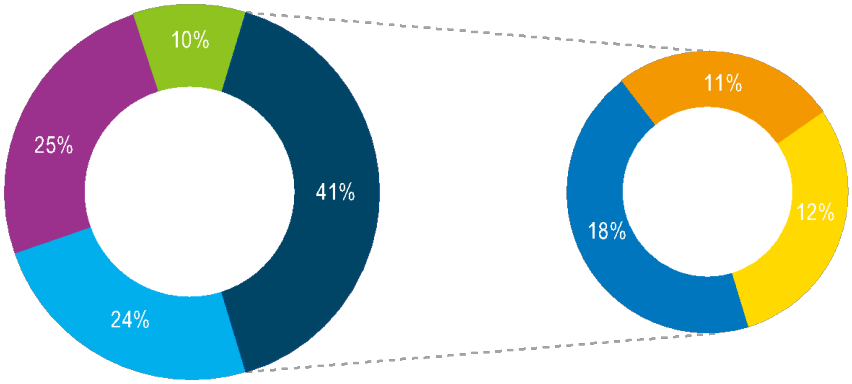
考虑到课程的时长与分配比例，我们可以得出以下结论：侧重于“伦理和社交影响”的课程通常比侧重“人工智能基础”或“理解、应用和开发人工智能”课程的课时投入更短。以下是针对各课程分领域的详细分析。

人工智能基础

人工智能基础领域包含数据素养、算法与编程，以及情景化问题解决。总体而言，人工智能基础课程领域占总课时分配的41%，其中算法与编程占据了该领域最大的课时比例，其次是数据素养和情景化问题解决，二者所占的课时比例几乎相同。

仅一门课程在人工智能基础领域没有分配课时，即亚美尼亚的信息通信技术课程。该课程将人工智能课程作为初中和高中必修的信息通信技术课程的一部分，总计投入7个小时的课时。**图9**为人工智能基础分领域及其课时分配占比的详细视图。

图 9. 人工智能基础课程领域的课时分配 (n = 21)



人工智能基础	41%	算法与编程	18%
伦理和社交影响	24%	数据素养	12%
理解、应用和开发人工智能	25%	情景化问题解决	11%
未详细说明	10%		

来源: UNESCO (2021b)

23门课程中有21门涉及算法与编程领域，亚美尼亚的信息通信技术课程和IBM的教育技术青年挑战课程除外。另有6门课程将10%甚至更少的课时分配给这一领域。相对而言，保加利亚的计算机建模、信息技术和信息学课程将65%的课时投入这一领域。总的而言，涉及情景化问题解决的人工智能课程最少。然而，包含该内容的人工智能课程平均在此领域投入了42.5小时的课时。这些课程和普通的人工智能课程不同，它们在情景化问题解决的教学上投入了大量时间，并将其作为基于项目的学习周期的一部分。

表10显示了涵盖各专题领域的课程数量，以及它们的课时范围和平均投入时间。

表 10. 人工智能基础课程领域的参与度-按专题领域划分

	算法与编程	情景化问题解决	数据素养
涵盖专题领域的课程数量 (n = 21)	19	14	17
课时范围	0 – 269	0 – 198	0 – 78
平均课时投入（总计）	50.0	28.3	21.5
平均课时投入（有课时安排的课程）	55.3	42.5	26.5
课时投入中位数（有课时安排的课程）	10.8	18.6	25.5

来源: UNESCO (2021b)

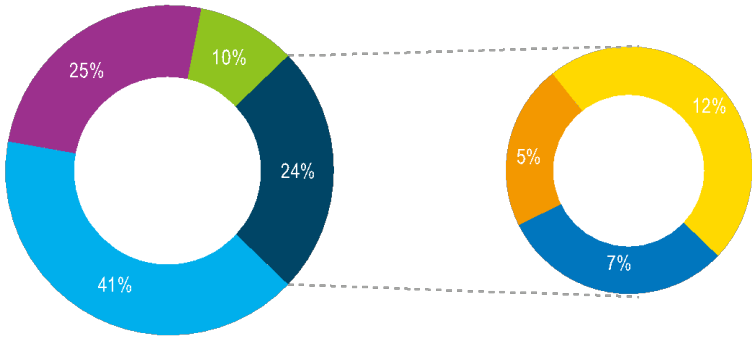
伦理和社交影响

伦理和社交影响的专题领域包含人工智能伦理、人工智能的社会影响，以及人工智能在其他领域的应用，后者与儿童及成人日常使用人工智能尤其相关。

总体而言，这类课程平均占据总课时的24%，但不同课程投入的课时大不相同，具体投入时间从亚美尼亚信息通信技术课程的0小时到科威特标准课程的185小时不等。从所占比例来看，卡塔尔的计算和信息技术（高科技方向）在该领域投入的课时不到5%。另一个极端是塞尔维亚的信息学和编程课程以及约旦的数字技能课程，后者将60%的课时投入于该专题领域。然而，从具体课时数来看，卡塔尔的人工智能课程在此投入了12小时，而塞尔维亚和约旦只投入了2小时。

当考虑这一课程领域下细分的专题领域时，很明显，有一半的课时被分配给人工智能在其他领域的应用，总体而言，平均有5%的课时用于人工智能的社会影响，7%用于人工智能伦理（见**图10**）。需要说明的是，卡塔尔的两门课程将人工智能在其他领域的应用作为数学、语言和科学课程的一部分，但并未对这一专题领域的课时投入做具体说明。

图 10. 伦理和社交影响课程领域的课时分配 (n = 21)



伦理和社交影响	24%	人工智能在其他领域的应用	12%
人工智能基础	41%	人工智能伦理	7%
理解、应用和开发人工智能	5%	人工智能的社会影响	5%
未详细说明	10%		

来源: UNESCO (2021b)

伦理和社交影响的课时投入少于人工智能基础的课时投入。同时，在其他领域应用人工智能的课时分配占比远远高于伦理和社会影响的课时占比。

然而更详细的分析表明，这一差异产生的原因在于涉及后两个专题的课程较少，同时，涉及该专题总课时较多的课程占比很低。因此，仅考虑针对各专题领域的课程时，三者的平均课时投入几乎相同，而人工智能在其他领域的应用的课时中位数最低（见**表11**）。

表 11. 伦理和社交影响课程领域的参与度-按专题领域划分

	人工智能在其他领域的应用	人工智能伦理	人工智能的社会影响
涵盖专题领域的课程数量 (n = 21)	18	17	12
课时范围	0–92	0–54	0–78
平均课时投入（总计）	11.9	10.8	8.1
平均课时投入（有课时安排的课程）	14.1	13.3	14.2
课时投入中位数（有课时安排的课程）	5.2	6	7.3

来源: UNESCO (2021b)

这些数据对政府认可的课程如何覆盖此类专题领域提供了若干重要见解。

- 首先，并非所有课程均涉及这一类别的专题领域，只有12门课程包含人工智能的社会影响领域。
- 第二，课程开发者似乎认为，可以通过较少的课时完成对三个专题的概念学习并实现学习结果。
- 第三，此类别的课程往往只是长课时课程中的一小部分，对于奥地利的数据科学和人工智能课程（144小时）、卡塔尔的两门计算和信息技术课程（两门均包含600小时的总课时），以及比利时法语区的信息技术数据库课程（680小时）而言，该类课程占比不超过其总课时的10%。
- 最后，此类别的课时投入往往在课时最少的课程中占据高百分比。在四门总课时分配最少的课程

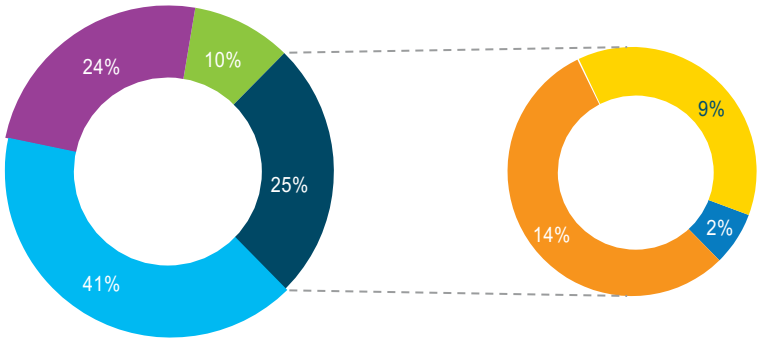
中，投入在伦理和社交影响这一领域的课时平均占比为45%，人工智能在其他领域的应用课程占比为33%，人工智能伦理占比10%，社会影响占比1.5%。

理解、应用和开发人工智能

这一专题领域包括理解和应用人工智能技术（如机器学习、深度学习、决策树和神经网络）；理解和应用现有的人工智能工具（如计算机视觉、分类器、自然语言处理和GAN生成器）；以及开发人工智能应用程序，这涉及到人工智能编程和新工具/技术的开发。

理解、应用和开发人工智能占据课程课时的25%。理解和应用人工智能底层技术占该类别的一半以上，开发人工智能应用程序平均占比最少，其课时分配只占2%（见**图11**）。

图 11. 理解、应用和开发人工智能课程领域的课时分配 (n = 21)



理解、应用和开发人工智能	25%
人工智能基础	41%
伦理和社交影响	24%
未详细说明	10%

开发人工智能应用程序	9%
理解和应用人工智能底层技术	2%
理解和应用人工智能技术	14%

来源: UNESCO (2021b)

与情景化问题解决以及人工智能社会影响的研究结果类似，开发人工智能应用程序的课时投入较少，主要原因在于很少有课程涉及这方面。其中只有6个国家的人工智能课程涵盖这一类别，课时投入从2%至14%不等。在这6个国家中，只有4个国家的人工智能课程在这一领域的课时投入超过10小时，即：中国的信息科技课程，英特尔的青年人工智能全球发展技能（全版本），微软的人工智能青年技能，卡塔尔的计算和信息技术（高科技方向)）。这四门课程中有三门要求学生每年至少在该领域学习150小时。在访谈中，来自这些国家的调查对象表示，他们认为小学教育的作用是让学生接触到人工智能及其在工作和日常生活中的应用，但人工智能应用程序的开发更适用于专门的本科课程。

调查对象强调，有关人工智能开发的课程必须充分建立在具有相关学科专业知识的基础上。最常见的例子是数学，学习者需要在数学原理、运用编码和算法的预期之间建立一致性。针对这一需求的回应各不相同。葡萄牙将大部分人工智能学习结果融入数学学科的“计算思维”当中，而中国则根据每年的数学学科要求来设计信息通信技术课程。麻省理工学院在为高中设计高参与度的人工智能开发课程时，最初以科学科目为目标，但课程开发人员发现，相对于人工智能的应用，科学老师对人工智能的开发更感兴趣。麻省理工学院认为，数学老师可能有更强的计算理论基础，而计算理论可以说是人工智能开发的基石。

表12显示了投入于理解、应用和开发人工智能专题领域的课时平均值、中位值和课时范围。

表 12. 理解、应用和开发人工智能课程领域的参与度-按专题领域划分

	开发人工智能应用程序	理解/应用人工智能底层技术	理解/应用现有人工智能技术
涵盖专题领域的课程数量(n = 21)	6	18	12
课时范围	0–30	0–128	0–207.5
平均课时投入（总计）	3.3	14.6	21.1
平均课时投入（有课时安排的课程）	11.7	17.0	36.9
课时投入中位数（有课时安排的课程）	11.3	5.5	11.1

来源: UNESCO (2021b)

有趣的是，人们更倾向于学习人工智能底层技术而非人工智能技术。这主要与应用环境有关，即有些人工智能工具专门用于帮助学习者通过主动或体验式的学习来解读和理解人工智能底层技术，如Teachable Machine MachineLearning4Kids。类似的人工智能工具如奥地利的数据科学和人工智能课程、亚美尼亚的信息通信课程、保加利亚的计算建模、信息技术和信息学课程、IBM 的教育技术青年挑战课程、两个版本的英特尔青年人工智能课程、印度的ATL人工智能模块、麻省理工学院的DAILy课程、微软的人工智能青年技能课程，卡塔尔的两门计算和信息技术课程，阿联酋的技术学科框架，以及加拿大育空地区的应用设计、技能和技术课程。

示例：奥地利的人工智能课程内容

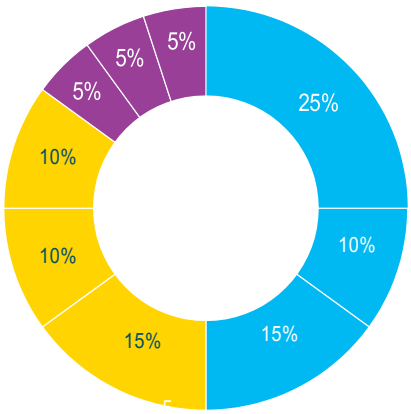
> 如果不采用数字技术，几乎无法想象现代教育和我们的工作要如何展开，也无法想象我们会如何参与到社会当中。
>
> -奥地利数字教育课程 (Federal Ministry for Digital and Economic Affairs, Austria, 2018)

奥地利的数据科学和人工智能课程包括数字基础知识，如使用操作系统存储和打印文件、设计演示文稿、以及使用电子表格和文字处理软件。该课程还涵盖针对数字媒体的类型和引发社会问题展开设计和反思，以及如何安全地使用数字媒体。

高中生主要接触以编程语言、算法和模拟为主的课程。他们学习数据素养的基本原理，包括收集数据、构建电子表格、进行分析和可视化。他们应用标准来评估数据源以及数字内容的可信度和可靠性。学生应该了解信息通信技术领域的职业（包括人工智能），以及新兴技术在社会中的应用。他们创建数字媒体，学习有关“云”以及如何与之建立连接的知识和网络计算机相关的理论。他们还将学习理解使用此类技术会产生的伦理困境，并将积极参与有关这些问题的社会讨论。最后，学生的任务是利用技术公开发表言论，并理解这一做法是如何反映民主进程的。

该课程作为计算学分的必修课在学校开设，包含144小时的课时。课时分配如下：50%（72小时）的课时用于教授人工智能基础：25%的课时用于教授算法与编程，10%的课时用于教授情景化问题解决，15%的课时用于教授数据素养。伦理和社交影响占据了35%的课时，即50小时：15%的课时用于教授人工智能在其他领域的应用，10%的课时用于教授人工智能伦理和人工智能的社会影响。剩余15%的课时用于教授理解、应用和开发人工智能，在这15%中，每个专题领域（理解和应用人工智能底层技术、理解和使用人工智能技术、开发人工智能应用程序）的平均课时为7小时。**图12**是按专题领域划分的奥地利人工智能课程分配占比。

图 12.按专题领域划分的课时分配



算法与编程	25%	人工智能在其他领域的应用	15%	人工智能底层技术	5%
情景化问题解决	10%	人工智能伦理	10%	人工智能技术	5%
数据素养	15%	人工智能的社会影响	10%	开发人工智能应用程序	5%

来源: Federal Ministry for Digital and Economic Affairs, Austria, 2018

人工智能课程学习结果

学习结果：分析方法

本节通过对学习框架和项目的分析，提取出课程的学习结果。根据本研究的目的，我们未对课程进行比较分析，而是展开了综合审查，以制定各年级的具体规定。审查结果展示了被引用为课程目标的参与类型。值得注意的是，本节并没有对中小学阶段人工智能课程中应当或不应当涵盖的内容提出要求，而只是代表了当前的实践情况。

除本节介绍的学习结果外，部分课程还涉及到后期高级技术研究工作所需的一些能力，但这些能力与人工智能无直接关系。这类能力包括：熟悉计算机及其操作系统；建立对互联网作为信息交流工具的认识；使用软件处理文字、声音、照片和图画；通过信息和通信技术创建及分享媒体；练习打字技能；使用协作软件；以及了解计算机网络。

学习结果：分类框架

本节的介绍与能力本位教育的主要方面相呼应。OCED(2016)将“能力”定义为知识、技能、价值观和态度的组合，在特定环境下应对复杂的需求。另外，重视认知、心理运动和情感领域之间的交互关系也非常重要。但为了方便参考，本报告仅将侧重于描述课程学习的三个结果，即:(i)知识，(ii)技能，(iii)价值观和态度。

知识涉及一般领域和特定领域的认知需求，它是获得能力的必要条件，通常使用“知道”、“理解”、“反映”和“比较”等动词描述。技能一般指心理运动方面，与技能相关的结果通常包括：“使用”、“创建”、“建立”、“修改”和“撰写”。在这一类别中，“技能”还包括对技术制品和产品的分析和修正。

价值观则包含以下指导原则：它决定了一个人在做决策或者采取行动时，对于轻重缓急的判断。价值观与信念一起构成了态度、属性，及其对行为影响的基础(IBE, 2013)。价值观和属性可能是隐性的或不明确的，可能在课程中明确陈述，也可能通过形容词嵌入到学习结果中，如“创造性的”或“独立的”，或形容词-名词复合词，如“批判性思维”。

在国际论坛和文献中，价值观的发展越来越受到重视。本文的目的不是质疑将价值观融入教育的可行性或合理性，而是引出隐含或明确融入人工智能课程的价值观和态度。然而，在此需注意的是，价值观是可变的，它们可以根据环境或情景而改变 (Haste，2004, 2018)。因此，本节提出的价值观应在本研究中特定(尽管多样)的国家背景下加以理解。

本报告介绍了被分析课程的隐性和显性价值观，OECD(2019)将价值观概括为以下四类：个体价值观，指个体如何定义和追求个人目标；社交价值观，指人际关系的处理方面；社会价值观，指涉及文化或社会方面的共同优先事项，并可能会被载入法律；以及人文主义价值观，这种价值观反映了超越国家和文化界限的共同优先事项。

知识和技能结果已在之前的章节(标题为“人工智能课程内容”)中提到，是按照课程领域和专题领域介绍的。这些课程领域为：人工智能基础，包括算法与编程、情景化问题解决和数据素养三个专题领域；理解、应用和开发人工智能，包括理解和应用人工智能底层技术、现有人工智能技术，和开发新的人工智能应用程序；以及伦理和社交影响，包括人工智能在其他领域的应用、人工智能伦理和人工智能的社会影响三个专题领域。

学习结果：调研情况（按人工智能课程领域分类）

知识

表 13.对知识结果的调研

专题领域	子领域	学习结果	受教育水平		
			小学	初中	高中
人工智能基础					
算法	计算思维	理解抽象概念	X		
		理解分解的概念	X		
		解释分解、抽象、模式识别和算法在计算中的作用		X	
		发现指令中的共性和规则（模式）			X
	算法定义和应用	理解算法的概念及其应用	X	X	X
		理解学习算法是一组由人类创建的指令，用于修改输入，从而创建输出		X	
		识别算法类型的示例 （分类器、生成器、回归算法）		X	
		了解并描述算法的日常应用			X
		认识算法在自动化数字流程中的重要性			X
	算法组件和过程	理解算法的各个部分（输入，改变输入的步骤，输出）		X	X
		理解训练、测试和运用算法的过程		X	
		比较和对比算法的搜索及分类能力			X
		分析递归算法的执行流程			X
		理解回归算法			X
		就算法使用高级数据结构的方法进行比较			X
编程	编程语言	积累基于块和其他编程工具的知识		X	
		理解各种编程语言及其产生过程		X	X
	表征与模拟	理解基于规则的推理		X	
		培养对人工制品开发过程中迭代过程的认识			X
		积累与真实世界物理系统的模拟/模型/计算抽象有关的知识		X	
		反思模拟的局限性和可能性			X
情景化问题解决		讨论和评估各种人工智能方法解决实际问题的能力和适用性		X	
数据素养		理解数据的趋势	X		
		理解数据收集和简单分析的原理和流程	X		
		理解如何收集、处理、分析、报告和使用数据		X	X
		理解信息来源的类型		X	X
		描述电子数据表中表格的基本结构		X	X
		描述数据和信息的特征			X
		评估大数据的管理能力（如仓储流程）			X
		讨论大数据云存储的优缺点			X
		比较结构化和非结构化的数据			X
		探索能有效表征数据的编码技术			X
		理解如何通过可视化/建模完成对大型数据集的转换和表征，使其服务于决策			X

专题领域	子领域	学习结果	受教育水平		
			小学	初中	高中
理解、应用和开发人工智能					
人工智能底层技术	人工智能的定义及构成	理解“弱”人工智能和“强”人工智能	X		
		描述与人工智能相关的基本术语		X	
		理解什么是人工智能（什么不是人工智能）		X	X
		理解人工智能的组成部分(数据集、学习算法和预测)		X	X
		理解并使用与人工智能和机器学习相关的基本及通用术语			X
		描述人工智能的基本特征			X
		理解人工智能的潜在算法			X
		理解人工智能的融合			X
	人工智能的数据使用	阐释如何使用数据进行预测		X	X
		描述数据流通过深度学习网络以解决分类问题的过程		X	X
	人工智能的历史	了解人工智能的历史及其发展过程		X	X
		理解人工智能应用程序开发的不同方法			X
	理解人工智能的工作原理	阐释人工智能技术的种类及其工作原理（有监督学习、无监督学习、强化学习、机器学习/深度学习）		X	X
		理解神经网络的工作原理及其组成部分（前馈、评估预测的准确性和反向传播）		X	X
		理解通用人工智能的概念及其面临的挑战		X	X
		了解生成式对抗网络的工作原理并识别其组成部分			X
		阐释启发式搜索及其工作原理			X
人工智能技术	计算机与人类知觉	比较计算机和人类知觉	X		
		理解计算机识别的过程	X		
		理解传感器的探测方法		X	
		理解传感器在数据收集中的作用			X
		理解人工智能和人类智慧之间的区别			X
	理解人工智能技术	探索人工智能技术和工具（如分类器）	X		
		理解自然语言处理的创建和使用过程		X	X
		探索自然语言处理的数据原理			X
		理解自主系统			X
		理解推荐系统及其背后的技术			X
		理解计算机视觉的创建和使用过程			X
		理解先进的技术（物联网、云计算）			X
		比较和对比物联网设备操作系统与典型的桌面操作系统			X
人工智能产品开发	设计思维	理解设计思维		X	X
	产品开发	理解产品开发周期			X
伦理和社交影响					
人工智能在其他领域的应用		识别/阐释人工智能在日常生活中的案例和应用	X	X	X
		描述人工智能如何驱动多种软件和物理系统			X
		了解人工智能的最新进展和应用			X
		了解人工智能和信息技术专业的重要应用领域			X

专题领域	子领域	学习结果	受教育水平		
			小学	初中	高中
人工智能伦理	伦理术语、定义和示例	理解“偏见”、“公平”和 “表征”等伦理术语在人工智能领域的含义		X	X
		就技术/人工智能使用中的人权和伦理问题进行反思		X	X
		描述人工智能的局限性			X
		理解人工智能可能引起的伦理考虑因素和困境			X
	获取	理解技术的获取过程可能引发的问题			X
	偏见	阐释编程人员的偏见如何影响人工智能规则的公平性			X
		理解信息质量对决策的影响			X
		理解算法偏见和偏见的类型/来源		X	X
		了解人工智能算法中减轻/减少偏见的方法		X	
		理解各种类型的偏见（表现形式、选择等）			X
		分析人工智能相关的明显公平或不公平的案例			X
	知识产权	理解知识产权的概念	X		
		捍卫由人工智能创造或改良的艺术作品的所有权		X	
		理解/尊重基本的知识产权法律		X	
	隐私和安全	培养网络安全意识	X		
		深入了解数字身份的概念			X
		理解数字服务提供商如何告知用户有关个人信息的使用情况			X
		理解个人身份信息可以用何种方式被使用和共享			X
	透明性/可解释性	了解图像和数据操作的机制			X
		了解可解释的人工智能的原理及其原则			X
	人工代理	理解人工智能和机器学习由人类控制		X	X
		理解计算机系统的可用性、安全性和可访问性是其设计的关键特征			X
		理解如何合乎伦理地开发和/或使用人工智能			X
人工智能的社会影响	人工智能的优缺点	理解人工智能如何造福人类	X	X	X
		反思新技术的优缺点	X	X	X
		概述人工智能在各种社会、教育和专业背景下的优势和劣势			X
	日常生活和工作中的人工智能	考虑新兴技术对社会（生活、工作和教育）的作用、重要性和/或影响	X	X	X
		探索可能颠覆人们生活、学习和工作方式的新兴技术		X	X
		培养数字公民的意识	X		
		理解人工智能对工作的改变(甚至在STEM学科之外)		X	
		理解STEM工作的好处和需求		X	
		了解自然、技术和社会之间的交互作用			X
	对环境的影响	理解技术对环境的正面和负面影响	X	X	X
		理解开发人工智能产品带来的计算和环境成本		X	
		理解如何减少计算和环境成本（采用更高效的模型，对成本和收益进行评估）		X	
		理解计算和环境成本如何导致人工智能产品开发中的不公平性		X	
	虚假和错误的信息	反思深伪技术的积极/消极影响及其带来的社会后果		X	
		反思生成式对抗网络技术的社会影响（如，作业造假）		X	
		了解错误信息的六个主要特征[22]		X	
		了解错误信息的传播方式		X	
	对性别平等的影响	培养在技术中产生的性别后果/机会相关意识			X

来源: UNESCO (2021b)

22 麻省理工学院 DAILy 课程中的引用: “煽动情感；两极分化；传播阴谋论；转移指责；冒充或伪造账户；以及“在网上引战”。

技能

表 14.对技能结果的调研

专题领域	技能描述	受教育水平		
		小学	初中	高中
人工智能基础				
算法	模式识别	X		
	遵循明确的操作（算法）指令并执行它们		X	X
	通过口头和书面的方式为操作（算法）制定清晰的指令		X	X
	通过迭代的方式创建算法及相关的流程图		X	X
	创建预测模型			X
	应用复杂的数据结构和基本算法（例如分类和搜索）			X
	从时间和空间两方面评估算法的效率			X
	优化计算过程（要求更少的步骤）			X
编程	利用编程控制机器人	X		
	使用基于块的编程构建简单的代码脚本	X		
	使用基于块的编程语言创建移动应用程序		X	
	使用基于文本的编程工具将算法转换为代码		X	
	使用一种或多种编程语言进行编码		X	X
	掌握基本的编程结构（如分支、循环、流程）		X	X
	评估用户界面（可用性、直观性）及其背后的技术流程			X
	使用、创建编码，并对编码过程进行反思（如密码，二维码）			X
	创建代码以操作本地数据文件			X
	开发软件以控制机器人或其他计算设备			X
	在多种编程语言中使用模块化的编程方法			X
	使用“面向对象的编程”开发应用程序			X
	开发安全且用户友好的应用程序，并考虑其可访问性			X
情景化问题解决	使用合适的工具创建简单的程序或网络应用程序，以解决特定的问题或执行特定的任务		X	X
	通过分解和模式识别，设计、开发和使用相应的策略来解决现实生活中的问题			X
	评估潜在的技术解决方案，并选择合适的方案，同时考虑私有软件和免费软件的使用			X
数据素养	保存、更改简单的数据库，并对其进行分类	X		
	创建可视化的数字和文本数据	X		
	使用适当的搜索策略从一系列来源搜索、筛选和收集数据	X	X	X
	组织收集到的信息（例如使用数据标记和分类）	X	X	X
	使用电子表格处理数据，进行计算并创建简单的图表	X	X	X
	使用信息通信工具管理和维护关系型数据库		X	X
	使用关系型数据库生成报告		X	X
	评估数据的质量、真实性和准确性		X	X
	使用标准来评估数据源的可信度和可靠性			X
	实施自动化的数据收集过程，并在各种物理媒体和云平台上管理数据的存储			X
	分析物联网数据流，并为异常情况（如极端大风）创建警报机制			X
	将非结构化数据转换为结构化数据			X
	使用软件工具或平台，组织、计算、呈现和保护数据			X
	创建SQL脚本来管理规范化数据库			X
	使用信息通信技术工具将数据转换为信息，以支持决策的准确性			X
	使用一系列模型和图表的方法来分析、预测和交流数据故事			X

专题领域	技能描述	受教育水平		
		小学	初中	高中
理解、应用和开发人工智能				
人工智能底层技术	根据特征将对象进行分类	X		
	构建决策树（纸面原型）		X	
	设计一套工作流程，从而训练和测试人工智能算法		X	X
	清理并准备用于分析和机器学习的文本数据			X
	为分类问题设计有监督学习解决方案并进行测试			X
	使用开源人工智能应用框架构建简单的智能系统			X
	阐释机器学习模型的性能（如使用混淆矩阵）			X
	识别各种媒体产品是否为生成式对抗网络			X
	在各学科领域（音乐、艺术、生物）中创建生成式对抗网络			X
	使用生成式对抗网络创建故事和插图			X
人工智能技术	使用具备学习能力的机器或类似的人工智能工具创建并测试分类器		X	
	创建具备支持功能的聊天机器人		X	
	构建并控制一个可使用人工智能的简单机器人		X	
	为自主机器人编程		X	
	为现有的人工智能算法设定一个新的目标		X	
	利用现有的人工智能技术开发新产品			X
	为进行自然语言处理构建和准备数据库			X
	创建具有适宜人机界面的聊天机器人			X
人工智能的产品开发	作为团队的一部分工作	X		
	在团队中使用设计思维的方法实施项目		X	X
	通过人工智能工具开发创新性方案			X
	管理一项技术开发项目			X
	验证所采用技术方案的正确性			X
伦理和社交影响				
人工智能应用	使用算法创造美术、音乐作品等。	X	X	X
人工智能伦理	保护个人数据及自己/他人的隐私	X	X	X
	识别人工智能算法中偏见的实例		X	
	识别人工智能算法的利益相关者/受益者		X	
	为算法建立伦理矩阵（利益相关者及其价值观）		X	
	研究在互联网上暴露的私人数据		X	X
	管理数字身份和声誉，并展示自己对数字足迹的理解			X
	查询表中混乱的数据，并在其中找到偏差			X
	进行自我辩护和补救（如, 权利受到侵犯）			X
	设计端到端的机器学习过程，最大限度地提高透明度并确保公平性			X
	为人工智能开发人员撰写指南，以确保人工智能合乎伦理			X
人工智能的社会影响	妥善处置技术	X		
	识别深伪（独立识别和人工智能辅助识别）		X	
	识别对平等使用信息技术造成威胁的发展，并确定行动方案		X	X
	批判性地比较、分析和评估信息和数字化内容（例如对操控的识别）		X	X
	避免与信息技术相关的身心健康风险和威胁			X
	参与公共讨论，帮助促进社会发展			X

来源: UNESCO (2021b)

价值观

表 15. 对价值观和态度结果的调研

预期培养的价值观/态度	相关知识和技能结果示例	受教育水平		
		小学	初中	高中
个体				
对信息通信技术的兴趣	探索现有的人工智能工具	X	X	X
	通过人工智能工具开发创新性方案	X	X	X
持久性/抗压力	使用编程的方法解决问题 测试、重新设计人工制品和产品	X	X	X
个体赋能	利用设计思维创建项目 研究在互联网上暴露的私人数据 确定当个人权利受到侵犯时可采取的补救途径		X	X
反思	反思人工智能会给“我未来的工作”带来的影响 阐释人工智能及其应用的作用和重要性 探索可能颠覆人们生活、学习和工作方式的新兴技术		X	X
批判性思维和方式	通过利用计算思维来设计、开发、使用策略，以解决现实生活中的问题 阐释编程人员的偏见是如何影响人工智能规则公平性的 比较、分析及批判性地评估信息和数字化内容(例如，对操控的识别)			X
创业	应用设计思维的方法制作原型 培养与创业原理/过程有关的意识，以实施创新性想法			X
社交				
协作/团队合作	作为团队的一部分进行工作 作为团队的一部分执行项目 作为团队成员在线协作	X	X	X
交流	使用生成式对抗网络创建故事和插图 为人工智能开发人员撰写指南，确保人工智能符合伦理			X
社会				
尊重他人	尊重他人 保护个人数据及自己/他人隐私	X	X	X
个体责任	妥善处置技术 理解人工智能和机器学习由人类控制	X	X	X
正直	理解在人工智能算法中缓解/减少偏见的方法 设计端到端的机器学习过程，最大限度地提高透明度和确保公平性		X	X
宽容	对不同的观点/立场保持宽容		X	X
人文主义价值观				
尊重环境/可持续发展的理念	理解技术对环境的影响 认识自然、技术和社会之间的交互作用 了解如何降低计算和环境成本	X	X	X
致力于公平	反思人工智能的获取过程 理解计算和环境成本如何导致人工智能开发过程中的不公平性		X	

来源: UNESCO (2021b)

示例：韩国的人工智能学习结果 [23]

2020年，韩国公布了中小学人工智能课程标准，该国目前也在开发本土的人工智能课程。地方政府和学校可以根据规定的课时和标准框架灵活地修改课程。2020年，韩国在高中实施了人工智能学校课程。由于该课程由校长自行决定是否开设，因此课程极有可能被推广到2367所高中使用。韩国目前有500所“人工智能教育领军学校”，专门致力于培养技术领域的人才。

该课程以小学、初中和高中的必修编程模块为基础，学生无需事先具备人工智能相关知识。

韩国人工智能课程的内容标准涵盖三个领域：

1. 理解人工智能，包括其分领域“人工智能与社会”和“智能代理”。
2. 人工智能原理及其应用，包括“数据”、“识别”、“分类、探索和推理”、“机器学习和深度学习”等分领域。
3. 人工智能的社会影响，包括“人工智能的影响”和“人工智能伦理”分领域。

图13概述了四个关键领域中针对部分学习目标的课程进展，包括：理解人工智能；数据；机器学习（包含分类）；以及社会影响。

图 13.韩国人工智能课程标准



来源: Ki-Sang Song 教授的访谈和书面资料

23 本节信息源自调查对象对采访问题的口头和书面回答。

课程实施

教师培训和支持

现有教职工的技能提升

大多数政府认可的课程所提供的培训都致力于提升现有教职工的技能。一些国家(如中国和葡萄牙)表示，他们通常会利用国家的培训项目或计划，对涉及到人工智能科目的教师进行培训。此外，在比利时等其他地区，由于教师培训通过教育网络进行，其培训计划往往比较分散，培训方式可能会因区域、语言和学校类型（例如公立或私立）的差异而不同。

非政府人员倾向于通过其他方式培训教师。对于麻省理工学院的DAILy课程，来自美国三个地区的教师参加了培训，其中包括通用会议，以及非政府组织合作伙伴主办的30小时的夏令营活动。行业合作伙伴通过远程或混合的方法为教师提供培训课程。例如，IBM与麦考瑞大学教育学院合作，在Coursera上开设了16小时的人工智能教师学习课程。该课程涵盖人工智能历史、人工智能与人类智慧的比较、开发和应用人工智能的伦理考虑因素等专题。一些供应商可以为客户提供培训资格认证。如，英特可尔为培训师和首席培训师提供认证，后者通常被定位为培训师的老师。

将人工智能整合到教师的职前培训中

在奥地利，教师培训的主要方法是将人工智能相关专题纳入到高等教育机构的教师职前培训中，该培训不止涵盖通用的人工智能专题，同时还包含指导教师如何使用人工智能支持教学法的使用以及教与学的过程。

为在职教师提供支持

除了建立标准以外，国家和地方政府还通过资源开发的方式支持人工智能课程的实施。例如，在塞尔维亚，人工智能课程的实施获得了在线工具的支持，包括视频、演示以及各种人工智能课程开发的交互式任务。国家或地方政府也会在人工智能课程实施前提供教材和评估指南等资源。

麻省理工学院的DAILy课程会为教师提供资料，包括幻灯片、课程要点和完整的教案，从而供教师使用或改编。IBM、英特尔和微软等行业合作伙伴通过面向全球开放的在线资源为教师提供各种学习途径和学习内容。这些合作伙伴还为人工智能课程的实施创建了针对具体情景使用的教师资源，包括手册、辅导员指南和人工智能教材。

学习工具和环境

除了利用现有的、与基础设施相关的举措来配置硬件和网络连接，人工智能课程还利用一系列的资源来支持其在校园内的实施。比利时和中国等国家由于并未集中决策人工智能工具和环境的配置问题，无法提供具体的资源支持情况。而在另一边，塞尔维亚等国家正在开发包含互动任务功能的在线工具，致力于通过该工具来优化课程。其他课程则利用现有的环境和工具，开发了一系列免费产品。来自奥地利和阿联酋的代表称：

> “我们使用 Jupyter Notebook/Lab、Python、PyCharm 和 Python 库(Scikit-learn、Keras、Tensorflow)来实施人工智能课程。
>
> 我们注重自然语言处理、图像分析和大数据分析。我们依据学生的年级水平，使用不同的资源和平台。我们使用的在线工具包括 Code.org、Microsoft and AI、MachineLearning4Kids 等，以及 IBM 和 AI Robotic Kits，如 MagkinderLabeeb、Fateen、Maker、Maker with Robotics Car 和 Raspberry-Pi 等均被用于各种人工智能项目。这些工具被用于训练不同的模型，理解机器学习的算法，并完成与人工智能相关的在线任务。更高年级的学生将学习 Python，以便运用不同的机器学习算法。

并非所有的人工智能课程均涉及编码或编程，但大多课程都包含这些元素，它们通常采用入门级的编程语言和工具，如PictoBlocks或Scratch。通过Python编程语言入门是常见的方法，尤其是面向高中开设的人工智能课程。尽管如此，部分课程也会使用到 HTML和Java。

人工智能课程中涵盖广泛的人工智能技术产品，如Alexa、GAN生成器、谷歌助手、Pix2Pix、PoseNet、机器人套件和仿真软件，以便学生可以探索人工智能在各学科领域的多种应用方式。学习人工智能开发的学生最倾向于通过免费软件(如MachineLearning4Kids和Teachable Machine)开发人工智能程序。这些工具允许儿童探索和构建机器学习模型，从而执行对象分类等任务。随着学生步入高年级，一些人工智能课程会进一步引入ML库和包括Scikit-learn在内的工具。

离线环境也在麻省理工学院的DAILy课程中得到了利用。除了鼓励学生持续探索在线工具和资源外，DAILy课程还包含离线游戏。例如，在一场小组活动中，学生们可以在生成式对抗网络中演示信息流的生成。而在另一场小组活动中，他们可能会在纸上为不同类型的意大利面构建一个决策树分类系统。以中国的信息科技课程为例，该课程需要服务广泛的地区和学校，而这些学校信息技术的获取和融合水平参差不齐，因此该课程提供了一系列的学习结果，但并未推荐适用于在线和离线方式的具体人工智能技术产品或工具。

根据人工智能课程侧重的课程领域，推荐以下工具和设备：

- **硬件和机器人**

人工智能课程所需的硬件包括计算机、平板电脑、笔记本电脑和互联网/网络接入。并非所有的人工智能课程均包含机器人或机器人技术。当有必要学习机器人的相关知识时，就需要使用以下套件，如Lego Mindstorm EV3,[24] Magkinder Labeeb,[25] 和/或Maker Robotics.[26]

部分课程会要求学生开发应用程序，并使用价格低廉的设备进行测试，这时就需要使用Raspberry Pi[27]等设备。

- **软件**

部分课程使用Ubuntu[28]开源操作系统，以替代其他更加昂贵的系统。

- **编程语言**

人工智能课程经常使用免费的编程语言，如：

- HTML[29]
- Javascript[30]
- Python[31]
- Micropython[32]
- NumPy[33]
- R[34]
- Scratch[35]

- **学习人工智能底层技术的工具**

为了理解和探索复杂的人工智能相关概念和人工智能底层技术，目前已经开发出了一些工具，包括在本调研中人工智能课程特别提及的：

- MachineLearningForKids[36]
- Teachable Machine[37]
- TensorFlow[38]
- Keras[39]
- OpenVINO[40]
- Scikit-learn[41]

24 详见 https://www.lego.com/en-us/product/lego-mindstorms-ev3-31313
25 详见 https://shop.ibtikar.io/en/magkinder-labeeb-151-pcs-set
26 详见 http://site.makerrobotics.com.br
27 详见 https://www.raspberrypi.orgorhttps://www.raspberrypi.com
28 详见 https://ubuntu.com/download
29 详见 https://www.w3schools.com/html
30 详见 https://www.w3schools.com/js
31 详见 https://www.python.org/psf
32 详见 https://micropython.org
33 详见 https://numpy.org
34 详见 https://www.r-project.org/about.html
35 详见 https://scratch.mit.edu
36 详见 https://machinelearningforkids.co.uk
37 详见 https://teachablemachine.withgoogle.com
38 详见 https://www.tensorflow.org
39 详见 https://keras.io
40 详见 https://docs.openvino.ai/
41 详见 https://scikit-learn.org/stable

- **数据库**

例如，当课程要求学生开发基于数据的人工智能工具时，就需要用到数据库，便于学生测试程序和优化算法，例如:

— Coco，一个大规模的对象检测、分割和字幕生成数据库[42]

— ImageNet，一个拥有超过 1400 万张图片的图像数据库[43]

- **学习人工智能技术的工具和资源**

当课程要求学生将学到的方法应用于遵循“使用-修改-创造”模式的技术时，需要以不同类型的人工智能工具案例作为参考。重要的是，要强调人工智能技术的“不可知法”，并向学生解释人工智能技术不应局限于特定的品牌或工具。

— GAN 图片生成器，如 GANpaint[44]

— 自然语言处理工具，如 Google Assistant[45] 和 IBM Watson[46]

不管是学术机构还是商业公司，都在面向社会提供在线的编程课程或人工智能学习空间。报告建议，为了防止人工智能课程与特定品牌或人工智能工具挂钩，国家或地方课程主管部门应当对公开许可或非商业性的学习工具进行管理和审核，并创建公共在线学习平台或学习空间，以支持人工智能教学工作的开展。

教学法建议

调查对象被问及人工智能课程或授课方式中应用的教学法建议。问答选项如**表16**所示，调查对象可以多项选择，也可以开放回答。

表 16.教学法建议及说明

教学法	定义
讲授与教学	指由教师主导的说教式课堂。信息由教师、辅导员或专家通过口头、印刷制品或多种媒体组合的形式传递。
小组活动	教学要求学生协作完成一项或多项任务。小组活动旨在使学生着手处理更复杂的任务，并练习团队合作等技能。
基于项目的学习	由教师引导，学生利用自身技能和能力识别和/或应对现实世界的挑战（在一段较长的时间内）。基于项目的学习的特点包括：学生自主、目标设定、协作，和对现实环境的调查(Kokotsakietal.,2016)。
基于活动的学习	在教师的引导下，学生可按照自己的节奏学习。基于活动的学习通常在教室内进行，它旨在培养学生独立、探索和实验的能力，通常与某项工作的演示相关。基于活动的学习的主要特点在于：学生可以积极参与学习和课堂合作 (Anwar, 2019)。

来源: UNESCO (2021b)

结果显示，几乎所有课程(89%)都依赖于教师的讲授与教学。同时，课程也强烈依赖于小组活动和基于项目的学习。基于项目的学习是许多国家和行业人工智能课程的突出特点。例如，来自葡萄牙的代表指出，葡萄牙的人工智能课程通过跨学科的方法，采用基于项目的学习：

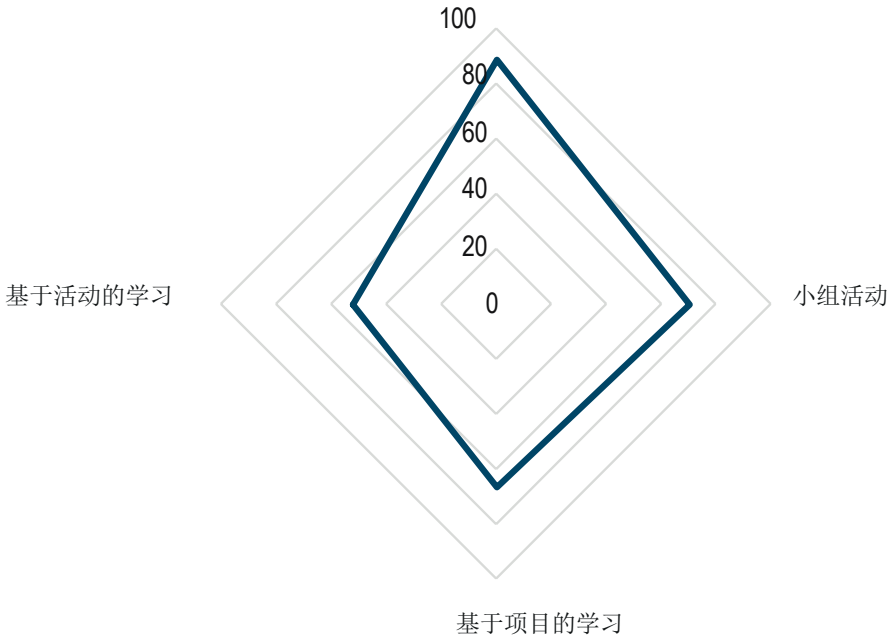
> “我们的人工智能课程规定我们必须使用以学生为中心的方法开展基于项目的学习。这是教师可以使用的主要教学法。我们还需要开发跨学科的方法，一个学科的知识必须与其他学科紧密联系。

然而，不同课程之间涉及的项目类型及投入的课时也不尽相同。项目可以被定义为有时间限制的活动，如使用人工智能软件执行翻译任务，使用人工智能工具创造艺术作品，或通过机器人套件开发或操控机器人。对于诸如IBM教育技术青年挑战课程、英特尔青年人工智能、卡塔尔的两门计算和信息技术课程、以及微软人工智能青年技能等课程，这类教学方法构成了

42 详见 http://cocodataset.org/#explore
43 详见 https://image-net.org
44 详见 http://gandissect.res.ibm.com/ganpaint.html
45 详见 https://assistant.google.com
46 详见 https://www.ibm.com/academic/home

人工智能课程参与的核心元素，学生们通过设计思维的引导性循环来创建人工智能项目。相比较而言，仅有14门人工智能课程推荐了基于活动的学习方式（52%），因此可以看出，这一方式并不太受重视(见图14)。

图 14. 教学法的平均使用情况 (n = 27)



来源: UNESCO (2021b)

此外，除三门课程外，所有课程都推荐了混合和/或远程学习模式(89%)，这表明课程的实施严重依赖于远程专业知识。学习评价、能力本位教育、建构主义（constructivism）、建构主义（constructionism）、体验式学习和以学生为中心的教学法也受到了认可或推荐。

有趣的是，允许采用远程方式学习的大多数课程均是由公共部门开发或在政府的监管下开发的。仅两门采用远程学习的课程由私营部门开发，即：IBM教育技术青年挑战课程和沙特阿拉伯的数字技能课程。

最后，调查反馈中包含的课程涵盖人工智能应用、伦理问题、工具和技术等内容，这些课程对数学或编程知识的依赖并不大，有时甚至完全不依赖技术。

示例：中国高中信息科技课程的实施

2017年，中国教育部发布了高中信息技术课程。全国22.5万所学校已将该课程设为必修课，覆盖超过1.8亿学生。该课程分为10个模块，包括2个必修模块，6个选修模块，2个学分选修模块，2个无学分选修模块。总体而言，该课程必修模块的课时要求为54小时，选修模块的课时要求为72小时，总计126小时。人工智能方面的教学被纳入必修模块中，即“数据与计算”和“信息系统与社会”；必修性质的选修模块意味着全体学生都必须选择其中一个模块进行学习，包括“人工智能基础知识”和“数据管理和分析”；以及选修模块 “算法初阶”。

该课程旨在引导学生理解人工智能是什么、人工智能的工作原理，以及围绕其应用引发的社会问题。虽然该课程在全国授权实施，但各省可根据其人口、现有资源和教育需求，针对这一课程的实施方案进行修改。来自中国的代表解释如下：

> 我们无法在中国各地实施一样的课程。各区域的需求也有所不同。例如，在发达城市，当地人熟悉各种设备、智能手机和许多其他产品。我们面临的挑战是如何引导他们合乎伦理地应用人工智能，尊重他人，为社会做正确的事情。在其他地区，学生对应用程序不太熟悉，所以挑战在于引导他们熟悉设备和应用程序。

该课程体系在发布之前已通过了专家组的审核，并在各年级学生中开展了试点教学，以摸准学生对课程内容的态度。课程体系在公布之前还将根据审核进行修订。

中国已经开展了一系列准备工作，包括开展研究、分析需求、开发资源、培训教师、安装基础设施、为学校提供必要的设备和材料，通过聘任更多教职工，以及聘请第三方机构和私营公司在学校担任兼职培训师的方式，提高课程教学能力。课程采用了广泛的教学方法，包括直接授课、混合和远程教学、小组活动、基于项目的学习和基于活动的学习。

为支持该课程的实施，政府将通过国家级的教师培训计划对所有学科的教师进行培训。培训项目的部分内容主要关注信息科技以及人工智能相关领域。中国教育部每年都会在假期期间举行两次培训会，要求全体教师每三年参加一次。为确保学生熟悉各种设备和应用程序，学校和教师同心协力，共同把控课堂上使用的技术种类。

在培训过程中，教师会接触多种品牌的设备、各种类型的平台和技术，而所使用的技术类型未在课程体系中明确说明。

主要结果和建议

本节列出的 9 个主要结果和 13 个建议涉及人工智能课程的四个主要阶段——课程的开发和认可、整合和管理、课程内容和学习结果，以及课程实施。

课程开发与认可

主要结果 1 – 仅开发和实施了政府认可的有限人工智能课程

迄今为止，11个政府已开发和实施了14门人工智能课程。尽管各国正通过制定政策文件，授权将人工智能纳入课程，但目前人工智能尚未被广泛地整合进中小学阶段课程。

建议1.1：还需开展进一步的研究，以确定在国家人工智能政策或战略文件中，可在多大程度上授权进行中小学阶段的课程改革，可在多大程度上执行这些授权，以促使人们更深刻地理解人工智能政策的政治机制，以及人工智能课程开发和实施过程中的促进因素和阻碍因素。

主要结果 2 –强有力的政府承诺和验证机制对管理课程开发中的利益冲突非常必要

人工智能领域涉及广泛的利益攸关者，其中很多利益攸关者在课程开发或交付方面非常活跃。人工智能课程的开发团队包括政府官员、行业专家、专业学者，有时甚至还包括教师。如果不具备较强的工作协调能力且投入不平衡的话，不同课程的目标可能会发生冲突。相反，较强的工作协调能力和验证机制可以帮助合作伙伴协调公共部门和第三方机构的工作，从而实现人工智能教育的国家目标。

建议2.1：在政府公开管理的情况下，需要以平衡、多学科和协作的方式进行人工智能课程编制。不论各国的发展状况如何，都能够获取来自国内外的行业、学科专家和教育从业者的专业建议，课程编制必须以学生的利益为主，同时需考虑如何以最优的方式对这些建议进行挑选、检验和去商业化。

建议2.2：使教师参与开发，以确保课程在实践中的可操作性。随着学生步入不同年级，教师可依据他们的知识、能力，针对在不同环境中应用技术的运筹挑战和动员学生的最佳教学方法，提供实用性建议。教师同时也是为学生解释复杂概念的专家，他们不仅可以为课程提供有价值的输入，还可以提供支持和培训材料。

主要结果 3 –需建立基于人工智能课程质量及有效性的证据基础

目前已发表的，关于人工智能课程评估的研究仍然较少，且尚未发现此类课程对学生人工智能能力发展和人工智能领域人力资源能力建设的影响。尽管人工智能课程的部分评估或试点教学的确会收集来自教师和学生的外部反馈，但除此之外的其他部分则仅依赖于专家对课程的审查。

建议3.1:应进行试点教学研究，同时须向教师、学生及学术和/或业界专家寻求反馈。应严格评估人工智能课程的实施及其对学生的影响，以提供证据基础。

课程整合与管理



主要结果 4 -资源开发和教师培训是课程整合的关键

近90%的课程在资源开发和(或)教师培训方面得到了支持。然而，仅略多于一半的课程涉及到通过需求分析为资源或培训方案提供信息。

建议4.1：开展循证式资源开发和教师培训。首先收集有关项目的信息，如部门内现有的人力资源能力，以及整合和实施人工智能课程所需的培训和支持。使教师参与资源开发，在为教师和学生分发资源之前，对其进行试用。为在职教师提供适宜的人工智能概念导论和教学方法介绍，并将其纳入高等教育机构的教师职前培训。将人工智能活动作为教师培训的契机。



主要结果 5 -政府认可的人工智能课程往往是选修课，或被整合归入学校的现有课程

大多数国家选择在现有的一个或多个学科中实施人工智能课程，或将其设为选修课，亦或通过跨学科的方式实施。在这些情况下，需确定现有课程中将会被删除或缩减哪些内容，从而为学生能够实质性地参与人工智能活动创造空间。课程开发者还必须考虑课程是被设置为包含几小时课时的子专题，还是在课外时间学习的“特殊专题”（例如，基于个人兴趣）。

建议5.1：为各年级的系列现有学科或专题开发课程整合指南，从而在不同专题领域实现人工智能的学习结果，而无需占用任何一门学科的大量教学时间。

建议5.2：考虑开设多课程方式相结合的人工智能课程，包括校外课程内容，如课外辅导和参与竞赛。

课程内容与学习结果



主要结果 6 -人工智能课程的目标和学习结果应聚焦于人在工智能时代工作和生活所需的主要价值观和技能

目前已达成共识的是：人工智能课程对于确保学生在智能时代拥有工作和生活的必备技能非常重要。然而，课程的开发目标非常多样且广泛，涉及的重点领域从接触人工智能到构建人工智能的相关专业知识。迄今为止，所开发的人工智课程显示了人们对任务递进的复杂性，以及能够或应该为不同年级学生考虑的各类学习结果的种种理解。人工智能课程设定的目标会影响其课时投入、课程内容和嵌入机制。用以学习人工智能底层技术、特定领域的人工智能技术和人工智能开发的课时非常有限，不足以满足开发创新型人工智能工具所需的创造力和技能要求。此外，如果不具备足够的有关人工智能技术和工具的知识，独立的伦理讨论不足以引导学生深入理解人工智能，也无法使他们具备在整个人工智能的生命周期中应用这些原则的能力。

建议6.1:人工智能课程应明确符合国际和国家的发展目标及战略。我们应着重考虑开发适应智能时代工作和生活的技能（可在特定环境中被进一步定义），并为开发创新型人工智能工具创造更多机会，同时将伦理纳入应用人工智能解决实际问题的情景中。

建议6.2:与课程专家、计算机科学家和教育从业人员协商，考虑课程的最终目标、开发动机和国家政策的授权情况，从而开发、采纳或调整一系列与年龄相适应的学习活动和结果。同时也应考虑各专题领域之间相互依赖的关系。

主要结果 7 –可通过离线和在线活动实现人工智能的学习结果

本调研中所包含的课程表明，尽管人工智能课程往往被要求覆盖实际应用、数据素养和人工智能开发的相关内容，但技术的获取不是理解人工智能及其社会影响的先决条件，教师和学生都可以免费获取一系列的资源、人工智能学习工具和技术。

建议7.1：在资源匮乏的情景下，人工智能课程可以侧重于理解人工智能、识别人工智能在日常生活中的应用、反思其社会影响，以及通过纸面原型或产品再设计练习，引入设计思维。

课程实施

主要结果 8 –基于项目的学习通常被用作人工智能课程的适宜教学法

在本研究中，三分之一的课程将基于项目的学习作为一种教学策略。此种学习方式带来的好处与实践技能的发展和解决问题的机会有关。

建议8.1：人工智能课程开发者应考虑采用创新的教学方法，创造跨学科的机会，以解决学生及其所在社区面临的现实生活挑战，同时，该方法也是培养批判性思维、创业精神、沟通和团队合作技能的一种方式。

主要结果 9 –人工智能课程不应与特定的技术或品牌挂钩

尽管开发适当的学习环境对人工智能课程的实施非常重要，但人工智能教育不应局限于特定的品牌或产品。学生需要掌握人工智能在各种领域和环境中应用的基本知识、可迁移技能和价值取向。由于新技术、新品牌的不断发展和变更，依赖于产品的课程可能会很快失去其有效性。当学生面对新环境或现实生活中的问题时，限定于特定品牌的知识可能将无法实现迁移。

建议9.1：课程的开发应注重学习结果以及人工智能原理和过程的应用，而非使用特定平台、设备或产品的能力。如果可能，人工智能课程应该涉及各种不同的技术产品。

建议9.2：为了能够使用一系列的人工智能技术和学习工具，如有需要的话，应对基本的基础设施进行投资，确保教师培训和其他学校支持机制有适当的架构（例如质量保证或绩效评估）来保障该基础设施可用于指定的学习结果。

总结性建议

在发达国家和发展中国家，随着人工智能进入工作和生活，人们在社会中的互动方式已经发生了彻底的变化。这也引发了重要的问题，例如关于人权的表达和保护、人工智能造成伤害的法律责任，以及人工智能开发和应用的哲学取向。人工智能将持续改变我们生活和工作的本质。因此，无论是否成为人工智能专家，对人工智能的基本理解构成了“受过教育的公民”这一概念的关键部分。

考虑到人工智能能力的重要性，以及人工智能领域的发展轨迹及其与其他领域的融合，令人惊讶的是，居然很少有国家追求将这一领域的培训正式纳入中小学教育。各国政府之所以在人工智能教育领域进行投资，是因为他们充分认识到人工智能技能不仅影响本国当前和未来的经济，同时也对公民能否充分参与社会生活至关重要。理解人工智能是什么、人工智能的工作原理和人工智能的能力，可以让学生更好地了解他们所处的世界，维护自己和他人的权利，并利用技术和数据为公共利益服务。

我们呼吁各国政府通过开发具有有序学习结果的、符合国家政策目标及国际人权和伦理标准的人工智能课程，确保所有公民都能享有这些机会。我们鼓励政府通过深入参与人工智能工具背后的算法和数据，对培养学生在人工智能方面的创造力给予充分重视，加强学生对伦理的理解。各国政府还应在人工智能课程的开发和实施过程中采用人道主义的方法，以保护包括数据隐私在内的人民基本权利，并促进包容、公平和性别平等。确保提供充足的非专有资源和基于需求的教师培训也同样至关重要。

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附录

发送给会员国代表的调查

联合国教科文组织对政府认可人工智能课程的调研

本次调查旨在收集政府认可的**中小学阶段或同等年级人工智能课程的一些高层次信息**。该课程可以是一门独立课程（例如，人工智能核心课程或选修课程），也可以是某一门课程的组成部分之一（例如，信息通信技术或其他学科课程中的人工智能单元或概念），也可以是一门课外课程，或分布于多门课程中。这些信息将作为联合国教科文组织调研的一部分，以确定正在开发和实施人工智能课程的国家、这些课程覆盖的年级、定位（独立课程或整合至其他课程），以及涵盖的内容。

您可能会对本次调查做出多个回应。若您的所在地的多门人工智能课程是由不同开发者开发或实施的，或者您希望明确指出各年级水平在人工智能课程的开发、认可、评估等方面存在差异，请针对每种情况分别作答。

非常感谢您的贡献，这将帮助我们丰富在教育领域中的全球人工智能知识基础。

您参与本次调查即被视为同意进行调查，并同意联合国教科文组织使用收集到的信息用于调研研究及后续出版物中。

基本信息

1. 在本次调查中，您的回答代表哪个国家、地区或国际政府间组织?（自由回答，简短回答）
2. 您是否了解在您所属国家/所在地中，针对中小学阶段学生的人工智能课程的开发或实施？[注意:该课程可能为独立课程（仅与人工智能相关），或嵌入到一门课程中（如信息通信技术/信息技术课程），或为跨学科课程（整合至多门课程）。课程的实施者可以是国家政府、私人机构或非政府组织。

   ○不知道

   ○是的，已开发和认可一门或多门人工智能课程

   若您所属国家拥有政府认可的人工智能课程，且如果您被推荐为联合国教科文组织人工智能课程调研研究的中心人员，如有其他问题，联合国教科文组织会与您进行后续沟通。
3. 请提供您的姓名
4. 请提供您的邮箱
5. 请提供其他联系方式

人工智能课程 1

[如果正在开发和认可多门人工智能课程，请分别提供每一项信息，在本页末尾说明额附加课程的数量，并移至下一页，或与联合国教科文组织联系以对人工智能课程进行调研。]

6. 人工智能课程的名称是什么?（自由回答）
7. 该课程的开发者是谁?（自由回答，简短回答）
8. 该课程的开发者是否为：

   ○公共部门（如政府）

○私营机构（如企业/行业）

○第三方机构（如非政府组织、民间社会组织、公益组织等）

○其他（填写）

9. 该课程如何获得认可?若以不同方式认可不同年级的课程，请在“其他”项下作出解释（请勾选所有适用的选项）

○国家政府已授权或认可在学校中实施该课程

○地方政府（如地区或省）已授权或认可在学校实施该课程

○一所或多所学校已授权或认可实施该课程

○该课程提供了行业认证

○以上都不是

○其他（自由回答）

10. 该课程在政府的学校课程框架中的定位是什么?（请勾选所有适用的选项）

○在学校作为带学分的必修课程

○在学校作为选修课或带学分的选修课

○在学校作为带学分的信息通信技术/信息技术必修课的一部分

○在学校作为带学分的信息通信技术/信息技术限选或自选选修课的一部分

○在学校作为一门跨学科课程

○作为学校的课外活动

○作为校外活动（如俱乐部、编程马拉松、家庭活动）

○其他（自由回答）

11. 目前有多少学校实施了该课程?若课程仍在开发中，请填写0。（回答限为0或以上）

12. 该课程覆盖多少学生?如果您不知道，请略过此题。

○男生数量

○女生数量

○总数量（如果不知道男女生各自的数量）

13. 该课程覆盖哪些年级?（请勾选所有适用的选项）

○小学前期: 小学 1 —2年级

○小学后期: 3年至小学结束

○初中

○高中

○其他（解释，自由回答）

14. 课程分配的总学时是多少?若有多个选项可用（例如，若存在一个扩展选项），请针对不同学时提供一个简短的标签，以描述其内容。（自由回答）

○小学前期: 小学 1 —2年级

○小学后期: 3年级至小学结束

○初中

○高中

15. 若您考虑开展人工智能课程，请您估计分配给以下各项的教学时间占总教学时间的百分比是多少?（若不投入时间，请略过此题）:

○算法和编程

○人工智能在信息通信技术以外领域的应用（如艺术、音乐、社会研究、科学、健康等）

○情景化问题解决

○数据素养（如统计、数据收集、预处理、数据建模、分析、阐释、可视化）

○人工智能伦理/伦理人工智能（如偏见、隐私等）

○人工智能的社会或社交影响（如劳动力的取代、法律框架的变化、治理机制的创建等趋势）

○理解和应用人工智能底层技术（如一般的机器学习、无监督/有监督/强化/深度学习、神经网络等）

○理解和应用人工智能技术（如自然语言处理、计算机视觉等）（如果是，请具体说明人工智能技术）

○开发人工智能应用程序（如自然语言处理、计算机视觉等）（如果是，请具体说明人工智能技术）

16. 该课程建议使用哪些学习工具和环境?（自由回答）

17. 为有效地实施该课程，教师进行了哪些准备或动员?（请勾选所有适用的选项）

○与课程实施相关的研究或需求分析

○为教师开发资源（教科书、教案等）

○针对课程和资源的教师培训

○为学校实施课程而雇用额外的教职工/职位

○私营或第三方机构参与学校的兼职培训

○升级学校的基础设施

○为学校/教室采购额外资源

○其他（自由回答）

18. 课程和/或任何相关的培训和资源中着重强调了哪些推荐的教学方法或教学法?（请勾选所有适用的选项）

○讲授与教学

○混合式学习（例如，部分面对面，部分远程的学习）

○远程学习

○小组活动

○基于项目的学习（例如，在较长时间内，学习者利用他们的技能和能力来识别和/或应对现实世界的挑战）

○基于活动的学习（例如，教师引导，学习者按照自己的节奏通过教师引导的活动取得进步）

19. 该人工智能课程是否经过评估?

○没有

○已经评估过，请阐释该课程的评估内容

20. 该人工智能课程在评估后是否进行了相应的修改?

○没有

○已修改，请阐释该课程的修改内容

21. 课程文档（包括草稿）是否可供调研小组审阅?

○可以

○不可以

22. [若有更多的人工智能课程，请选择数量并移至下一页][47]

47当需要添加更多人工智能课程时，问卷对多达13门课程重复第6到第21个问题。

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中小学阶段的人工智能课程

对政府认可人工智能课程的调研

法规本身不足以确保人工智能服务于教育和人类的共同利益。

所有民众都需要具备一定程度的人工智能素养，其中包括与人工智能相关的价值观、知识和技能。本报告介绍了联合国教科文组织关于中小学阶段人工智能课程全球调查的主要结果和建议。报告显示，只有11个国家开发了中小学阶段的人工智能课程并予以认可，另外有4个国家的人工智能课程尚在开发当中。我们强烈呼吁会员国为中小学学生开发人工智能课程，并通过建立更加强有力的机制，审查非政府机构提供的人工智能课程，平衡私营部门驱动的途径。该报告还表明，人工智能课程的学习结果应更加注重培养人工智能技术的创造力和情景伦理。教师培训是确保人工智能课程实施的关键，教师需要在设计和促进基于项目的学习方面接受培训，该种方式也是目前人工智能课程中最常用的教学方法。

该报告还建议，在向特定领域引入人工智能技术时，应采取“不可知法”对待人工智能的品牌和产品。

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4 优质教育

可持续发展目标



K-12 AI curricula

A mapping of government-endorsed AI curricula

ED-2022/FLI-ICT/K-12

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Education 2030

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K-12 AI curricula

A mapping of government-endorsed AI curricula

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Objective and scope of the report

As AI technology represents a new subject area for K–12 schools worldwide, there is a lack of historical knowledge for governments, schools and teachers to draw from in defining AI competencies and designing AI curricula. This mapping exercise analyses existing AI curricula with a specific focus on the curriculum content and learning outcomes, and delineates development and validation mechanisms, curriculum alignment, the preparation of learning tools and required environments, the suggested pedagogies, and the training of teachers. Key considerations are drawn from the analysis to guide the future planning of enabling policies, the design of national curricula or institutional study programmes, and implementation strategies for AI competency development.

Scope of the mapping

UNESCO is investigating the current practices of developing and implementing AI curricula in primary and secondary school education from a global perspective. 'AI curricula' in this study refers to structured programmes of learning on AI-related topics that: 1) are endorsed by either national or regional governments; and 2) target learners in general school education from kindergarten to grade 12. This study does not cover AI curricula designed for specialized technical and vocational education and training (TVET) institutions, higher education institutions, or informal learning opportunities.

Introduction

A diverse range of AI technologies are currently in use internationally, and there is a growing recognition of the importance of AI in the context of labour and in terms of its impact on everyday life. There is 'wide consensus' that AI will 'affect occupations at all levels of pay and education' (Royal Society UK, 2018, cited in the Microsoft Computer Science Framework, 2021). A 2018 analysis by McKinsey concluded that by 2030, 70 per cent of global firms are expected to adopt at least one type of AI technology. However, AI adoption will widen existing gaps between countries (Bughin et al., 2018*a*). Currently, in the United States, machines perform as many as 30 per cent of workforce tasks (Kelly, 2020). Additionally, increasing mismatches between skills being taught in schools and TVET institutions and skills needed by the job market are anticipated in correlation with higher rates of automation and AI integration (Bughin et al., 2018*b*). The COVID-19 pandemic has only increased the pace of automation, which may result in as many as 1 in 16 workers[1] requiring retraining by 2030 and a further decline in the availability of middle- and low-skill jobs (Lund et al., 2021).

The impact of AI technology is not limited to the workforce. AI has profound implications for culture, diversity, education, scientific knowledge, and communication and information, especially insofar as they concern peace, sustainability, gender equality, and the specific challenges of Africa (COMEST, 2019). These are all areas of significant interest to both international and national bodies that focus on development and policy. Citizens are increasing their interactions with AI, knowingly or unknowingly. AI has been deployed to drive cars, automate customer service, identify targets for military bombs, screen applicants at national ports of entry, direct policing efforts, determine grades, select university entrants and scholarship recipients, and make decisions about personal finance (Engler, 2021; Frantzman and Atherton, 2019; Shiohira, 2021).

International policy guidance suggests that common areas should be pursued through different contextualized approaches such as promoting the inclusive and equitable use of AI in education; leveraging AI to enhance education and learning; fostering skills development for jobs and life with AI; and safeguarding education data so that its use is ethical, transparent and auditable (UNESCO, 2019*a*). However, currently relatively few initiatives focus on AI in K–12 contexts, leading to a recent recommendation that policy-makers should 'provide an enabling policy environment and curricular spaces for exploring AI' (Miao et al., 2021, p. 34).

As a leading part of the international community and conversation on technology in education, UNESCO has led a number of important developments in the AI in/for Education space.

In 2015, the *Qingdao Declaration* (UNESCO, 2015) included a point on exploring the potential of big data to enhance online learning, inform an understanding of student behaviour, and improve the design and delivery of online courses. The declaration urged that 'governments must develop policies and systems to ensure secure, appropriate and ethical use of data, including safeguarding the privacy and confidentiality of students' personally identifiable information'.

- The *Beijing Consensus on Artificial Intelligence and Education* (UNESCO, 2019*b*) includes a series of recommendations and considerations for AI in Education. Demonstrating a strong focus on equity and inclusion, one of the recommendations in the consensus is to 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.
- As part of the *UNESCO Strategy on Technological Innovation and Education (2022-2025),* in addition to an observatory and capacity building, the Organization seeks to develop standard-setting instruments and normative tools, including guidelines and frameworks, 'to strengthen the digital competencies (understanding, skills, and values) of teachers and learners and ensure a human-rights-based, safe, ethical, and meaningful use of

1 Eight countries were included in this analysis, namely China, France, Germany, India, Japan, Spain, the United Kingdom, and the United States, accounting for almost half the global population and 62 per cent of GDP.

technologies in a lifelong learning perspective' (UNESCO, 2021*a*). Transversal areas of action are the expansion of access to education, particularly for marginalized groups and individuals, and the quality of teaching and learning.

- UNESCO published *AI and Education: Guidance for policy-makers* in April 2021 with an aim to foster AI-readiness among policy-makers (Miao et al., 2021). This report provides an orientation for its target readers on AI, including opportunities, risks, key definitions, trends in AI, implications for teaching and learning, and how education can prepare students for the AI era. It concludes with recommendations for local policy planning.
- In October 2021, UNESCO launched AI and the Futures of Learning,[2] a project with three independent but complementary strands: (1) a report proposing recommendations on AI-enabled futures of learning; (2) guidance on ethical principles for the use of AI in education; and (3) a guiding framework on AI competencies for school students.

The everyday realities of the current uses of AI and its impact on the world of work spur a sense of urgency to create international consensus on its acceptable roles in society, the expected humanistic considerations in its development and deployment, and how to equip children with the competences they will need to successfully navigate the existing – not the future, but the existing – world. The *Beijing Consensus on Artificial Intelligence and Education* (UNESCO, 2019*b*) calls on all Member States to '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'. The Consensus endorses a 'humanistic approach' to 'preparing all people with the appropriate values and skills needed for effective human–machine collaboration in life, learning and work, and for sustainable development'. To support the implementation of the Beijing Consensus, on 7 and 8 December 2020 UNESCO hosted the International Forum on AI and the Futures of Education: Developing Competencies for the AI Era. Participants at this event considered the competencies that citizens require:

> "The world's citizens need to understand what the impact of AI might be, what AI can do and what it cannot do, when AI is useful and when its use should be questioned, and how AI might be steered for the public good (Miao and Holmes, 2021, p. 6).

The Forum emphasized the centrality of human-oriented competencies, such as an understanding of the ethics of AI and its social impacts, and technology-oriented competencies, such as the skills and knowledge to use, interpret and develop AI. Subject-specific and interdisciplinary approaches to AI in education were recommended, including building on existing ICT curricula and integrating analyses of the opportunities and impacts of AI into humanities, science and art courses (Miao and Holmes, 2021).

This report contributes further to the understanding of AI in K–12 education, in particular the ways in which students are currently being prepared for life and work in the AI era, by providing an analysis of the global landscape of government-endorsed AI curricula for grade school education and their design, content and implementation. This report is intended to inform the creation of supportive tools and frameworks, with a view to enabling the development of a guiding framework on AI competencies. It also forms one part of the work laid out in the *UNESCO Strategy on Technological Innovation in Education (2022-2025)* (UNESCO, 2021*a*).

A primer on AI terms and technologies

This report engages a range of concepts and terms from both AI-specialist and education-specialist fields. Despite the ubiquitous presence of AI in fields such as marketing, finance, and increasingly education, some decision-makers and practitioners may be unfamiliar with some of the terms used in this analysis. Similarly, it is not guaranteed that all AI practitioners and decision-makers will be aware of prominent trends in pedagogy referenced in the curricula. Therefore, this section provides a brief primer on some of the technologies, terms and pedagogies discussed in this text, to equip readers with a general understanding of each main concept. First, five terms from the field of AI are explained in turn, and then the section on pedagogical concepts looks at several concepts including 'competence-based evaluation', 'constructivism', 'constructionism', and 'design thinking'.

2 See https://events.unesco.org/event?id=2883602288

Nearly all of these concepts and terms have generated at least some amount of academic debate, and have both proponents and detractors, but the purpose of this report is not to delve deeply into conflicting viewpoints. This should not be taken as an exhaustive exploration.

Artificial intelligence

The term 'artificial intelligence' was coined in 1956 when Marvin Minsky and John McCarthy hosted the Dartmouth Summer Research Project on Artificial Intelligence (COMEST, 2019; Haenlein and Kaplan, 2019). AI has gained popularity owing to the rise of big data and the exponential growth of computing power (Haenlein and Kaplan, 2019). The definition of AI has expanded and evolved over time (Miao et al., 2021), and now refers to machines that imitate some features of human intelligence, such as perception, learning, reasoning, problem-solving, language interaction and creative work (COMEST, 2019).

The analysis in this report divides AI into two categories, 'AI techniques' and 'AI technologies'. The former encompasses the methods used to build different types of AI, while the latter refers to the fields of study and products which are created by those techniques.

AI techniques

The AI techniques included in the curricula athat are analysed in this report are briefly described below:[3]

- **Classical AI** is rule-based and uses conditional if-then statements to generate outputs. Rule-based reasoning can be used in technologies such as chatbots (e.g. 'If the input contains the words "what", "price" and "?", then return the listed product price amount').
- **Machine learning (ML)** refers to any type of computer program that can 'learn' without explicit programming by accessing and processing large amounts of data. What is meant by 'learn' is that the program can produce new outputs without being explicitly 'told' what those outputs should be, as would be the case in classical AI. The remainder of this list is comprised of some of the many different sub-categories of ML.
- **Supervised learning** is a type of ML which is trained on known, labelled data to produce outputs. For example, a **classifier** is an algorithm that is designed to sort things into categories (e.g. 'spam' or 'not spam') using labelled data. **Decision trees** are a type of classification algorithm in which a series of 'nodes' (decision points, represented as questions) lead to 'branches', where the results of different response options are separated. For example, in the MIT DAILy Curriculum, which is discussed at length later in this report, students create a decision tree to classify different types of pasta. One node might ask, 'Is it longer than four inches?', with spaghetti, linguine, and other long pastas on one branch to the next node and macaroni, farfalle, and other short pastas on another branch.
- In **unsupervised learning**, machine learning generates outputs based on clustering similarities in groups of unknown and unlabelled data.
- **Reinforcement learning** is a type of ongoing ML which is trained to maximize a reward (for example, to return the maximum amount of currency on an investment).
- **Neural networks** are ML algorithms that are modelled on animal brains. They are comprised of input layers, hidden layers and output layers. In the hidden layers, data is processed in nodes based on its value and an assigned weight, and only data that passes a given threshold is allowed through. Filtered data makes its way through one or more hidden layers to the output layer. 'Learning' in neural networks occurs through 'back propagation', an algorithm which seeks to minimize error by adjusting the weights in the hidden layer(s) of different nodes based on the correctness and influence of each node's inputs.
- **Deep learning (DL)** refers to neural networks with multiple hidden layers. While ML in general relies on data that is structured (e.g. selected, labelled and organized into tables), DL can process unstructured data such as text and images. Neural networks and/or deep learning are used in image and speech recognition.
- **General adversarial networks (GANs)** are a type of machine learning which is designed to generate new content, for example images.[4] A GAN includes two deep neural networks. One of these generates content and the other evaluates it. GANs do not work particularly well with text – yet.

3 The explanations given here are derived from Miao et al. (2021), supplemented by examples and definitions from the curricula included in this report, in particular the MIT DAILy Curriculum, the AI4K12 Curriculum Framework, and the IBM Youth Challenge.

4 For example, GAN technology can be used to generate images of people that do not exist (see https://www.thispersondoesnotexist.com)

AI technologies

The AI technologies included in the curricula that are analysed in this report are briefly described below:

- **Chatbots** are computer programs designed to simulate oral and/or written conversation.[5]
- **Computer vision** is the field of AI that is concerned with deriving and using information gathered from images and visual inputs. Computer vision drives products such as automated highlight reels, self-driving cars, and quality-control tools (for the identification of defects) in manufacturing.[6]
- **Natural Language Processing (NLP)** is based on combining computer science with computational linguistics, an interdisciplinary field for studying human language, in order to create rule-based models of human speech or text that can be used by computers. This enables computers to process and appropriately respond to human language. This technology drives computer translation from one language to another and the ability of technologies such as satellite navigation or digital assistants to respond to verbal commands.
- **Sensors** are devices or systems that measure physical properties such as temperature or pressure and transmit this data to other electronics (such as a computer processor). Sensors are one method of gathering the data used in AI. They are a fundamental part of the Internet of Things (IoT), systems in which actions are undertaken without human intervention based on inputs from different sensors (Mahdavinejad et al., 2018). A simple example would be an IoT irrigation system that gathers information from sensors embedded in soil and activates a watering device accordingly.[7]

Ethical AI

As noted, AI has a wide range of applications and many demonstrable benefits. For instance, AI provided important insights and issued alerts early in the COVID-19 pandemic. However, the use of AI also raises a number of ethical considerations. Bias can be introduced into AI through the datasets used and the choices of developers, leading to discrimination. Due to elements such as the hidden layers of some types of AI, the processes and factors in AI decision-making cannot be seen, checked or redressed by humans, raising issues in terms of explainability and transparency. Other challenges include balancing the use of personal data with the individual right to privacy; the security of data and potential exposure to cyber-crime; and the reinforcement of prior beliefs by AI algorithms based on user interest, which can limit people's exposure to ideas and information and, some argue, infringe on an individual's right to freedom of expression (UNDESA et al., 2021).

The *First Draft of the Recommendation on the Ethics of Artificial Intelligence* (UNESCO, 2020) highlights some of the key ethical challenges of AI, noting impacts on decision-making, employment and labour, social interaction, health care, education, media, freedom of expression, access to information, privacy, democracy, discrimination, and weaponization. The Recommendation proposes that AI should be monitored by third parties to ensure it is trustworthy and works for the good of humanity, individuals, societies, and the natural environment and its ecosystems. It sets out ten principles for ethical AI:

1. **Proportionality and no do harm** suggests that AI should have legitimate objectives and aims that are appropriate to the context, and based on rigorous scientific foundations.
2. **Safety and security** suggests that AI should not cause damage and must protect against security risks throughout its life cycle.
3. **Fairness and non-discrimination** suggests that AI systems should avoid bias, and that access to AI and its benefits should be shared at national, local and international levels, and be equally distributed without preference for 'sex; gender; language; religion; political or other opinion; national, ethnic, indigenous or social origin; sexual orientation; gender identity; property; birth; disability; age; or other status'.
4. **Sustainability** suggests that the social, cultural, economic and environmental impact of AI technologies should be continuously assessed in the context of shifting goals.
5. **Privacy** suggests that data for AI is collected, used, shared, archived and deleted in ways that protect the individual agency of data subjects, and that 'legitimate aims' and a 'valid legal basis' are in place for processing personal data.

5 See, for example, https://towardsdatascience.com/building-a-chatbot-with-rasa-3f03ecc5b324
6 For more information, see https://www.ibm.com/topics/computer-vision
7 See for example https://www.digiteum.com/iot-solutions-agricultural-irrigation-system

6. **Human oversight and determination** suggests that humans or other legal entities bear responsibility for AI ethically and in law.
7. **Transparency and explainability** suggests that people should be aware of when decisions are based on AI algorithms, and that individuals and social entities should be able to request and receive explanations for those decisions, including insights into factors and decision trends. **Explanability** is detailed further: 'outcomes, and the sub-processes leading to outcomes, should be understandable and traceable, appropriate to the use context'.
8. **Responsibility and accountability** reinforces the principle of human oversight and determination, and suggests that impact assessment, monitoring, and due diligence mechanisms should be in place to ensure accountability for AI systems. *Auditability*[8] must be ensured.
9. **Awareness and literacy** refers to the responsibilities of governments as well as the public sector, academia and civil society to promote open and accessible education and other initiatives focused on the intersections of AI and human rights, in order to ensure that 'all members of society can take informed decisions about their use of AI systems and be protected from undue influence'.
10. **Multi-stakeholder and adaptive governance and collaboration** suggests that states should regulate data generated within and passing through their territories; that stakeholders from a broad range of civil organizations, and the public and private sector should be engaged throughout the AI life cycle; and that measures need to be adopted to allow for meaningful intervention by marginalized groups, communities and individuals.

AI literacy

The *synthesis report of the UNESCO International Forum on AI and the Futures of Education under the theme of Developing Competencies for the AI Era* (Miao and Holmes, 2020) noted that the world's citizens need to understand what the impact of AI might be, what AI can and cannot do, when AI is useful, when its use should be questioned, and how it might be steered for the public good. This requires everyone to achieve some level of competency with regard to AI, including knowledge, understanding, skills, and value orientation. Together, these might be called 'AI literacy'. AI literacy comprises both data literacy, or the ability to understand how AI collects, cleans, manipulates, and analyses data; and algorithm literacy, or the ability to understand how AI algorithms find patterns and connections in the data, which might be used for human-machine interactions. This is an attempt to frame the scope, structure, and main categories of the emerging field of AI literacy. This term has been used to guide the study presented in this report.

Pedagogical concepts and terminologies

'Competence-based education' (CBE) is a model often pursued in higher education and TVET, but it is increasingly being applied in various forms to K–12 education. CBE is intended to transition education from models of fixed time and flexible learning, to flexible time and fixed learning. In CBE models, students are expected to demonstrate applied knowledge, skills and values in context through assessments, and they are given as much additional support as needed until they meet the required benchmarks (NCLSorg, 2017).

At the heart of CBE is the concept of 'competence', a term which has evolved to describe 'the mobilization of knowledge, skills, attitudes and values to meet complex demands' (OECD, 2019, p. 5). The intended competencies of a curriculum are usually expressed through learning outcomes, or what a student is expected to know, understand and be able to do upon completion of a course of study (Biggs and Collis, 1982; Cedefop, 2017; Kinta, 2013). The terminology 'learning outcome' is a modification of the earlier term 'learning objective' which ensures that the focus of the statement is on students' actions or achievements rather than those of lecturers, and further are defined using measurable applications (Lopez et al., 2015; Sinha, 2020). The relationship between curricula, learning outcomes and competence is complex in actualization but theoretically quite direct: a curriculum describes a set of intended learning outcomes, and assessments of students demonstrate their attainment of these outcomes through the application of knowledge, skills and attitudes/values within the domain or subject of study and, ideally, in new domains – what Biggs and Collis's (1982) SOLO[9] taxonomy refers to as 'extended abstract' capacity.

8 While auditability is not explicitly defined in the Recommendation, this term refers to the ability of third parties to access, review, monitor and criticize algorithms (Jobin et al., 2019).
9 SOLO stands for 'structure of observed learning outcome'.

The frameworks and curricula examined for this report also reference constructivism, constructionism, computational thinking and design thinking.

'Constructivism(s)' is a broad series of concepts in academia that apply to the ways in which knowledge is created or constructed (and at times co-constructed) by individuals through interactions with each other and their physical, cultural and institutional or systemic environments (Taber, 2016). The types of constructivism often applied in education are built largely upon the work of Piaget (1972), who outlines a theory of types and forms of learning which are and are not accessible to children at various stages of development; for example, concrete application would precede abstraction.

A related concept is 'constructionism', the philosophy that students learn best through applying knowledge to projects which hold a personal interest for them (Papert and Harel, 1991). Constructionism is particularly applicable to digital curricula due to its origins in the domains of ICT and mathematics and its preoccupation with the ways in which meaning is generated through the process of engaging, manipulating and changing digital artefacts (Kynigos, 2015). Though constructivists and constructionists have a common base, constructionists challenge the hierarchies of knowledge that were set out by Piaget (1972), generating arguments that students can productively engage with more complex concepts at younger ages through the use of digital media and methods such as block-based programming (Papert, 1996).

Computational thinking, or the series of mental and physical processes undertaken to build a digital solution to a problem (identifying a problem, breaking it down into parts, building and assimilating solutions, and testing and refining them), is theorized to apply to an array of domains outside of computer science (Lodi and Martini, 2021). The four established 'parts' of computational thinking are sometimes cited as decomposition, abstraction, analysis and algorithms (Kush, 2019). Lee et al. (2011) studied a range of computational thinking initiatives in grades K–12 and determined that its processes could indeed be deployed by students of varying demographic backgrounds. They further proposed a 'use-modify-create' learning progression model for engaging with computational thinking, and noted that skilled teachers, developmental considerations and appropriate technology were critical support mechanisms.

One final tool which is presented in the context of some of the curricula included in this study is 'design thinking'. It is presented as 'an analytic and creative process that engages a person in opportunities to experiment, create and prototype models, gather feedback, and redesign' (Razzouk and Shute, 2012). Originally developed in fields such as archeology, marketing and economics (Buchanan, 1992), design thinking started emergning within industry in the early 1990s, where it was developed as a consumer-oriented methodology to design innovative products or business models, particularly those involving technology (Hobcraft, 2017). The process of design thinking includes empathizing (for example with consumers), defining a problem statement, generating ideas for solutions, and then prototyping and testing in an iterative design cycle until a desirable innovation is achieved (Hasso Plattner Institute of Design, 2010). In schools, design thinking can offer a clear procedure for responding to a need for digital as well as interdisciplinary activities and competences.

Existing frameworks of reference on AI curricula

There are a few recent initiatives to map or create AI curriculum frameworks for grades K–12. These include three that are detailed in this section: AI Literacy: Competencies and Design Considerations, the AI4K12: K-12 AI Guidelines,[10] and the Machine Learning Education Framework. This is not an exhaustive list, as a number of NGO, industry and academic organizations and/or individuals have developed AI curriculum frameworks to support their own programmes and undertakings. Some of these frameworks are in use by governments, such as the Microsoft Computer Science Framework, and are included in the learning outcomes mapping later in this report. The three frameworks covered in this section were developed with the primary purpose of informing the development of AI curricula by a range of partners and are not linked to specific products or courses.

10 See https://ai4k12.org

AI Literacy: Competencies and Design Considerations

Long and Magerko (2020) present a series of competencies and design considerations for AI literacy based on a scoping study of existing research, which sought to determine emerging themes in 1) what AI experts believe a non-technical audience should know, and 2) common perceptions and misconceptions among learners.

Their scoping study reveals 17 competencies and 13 design considerations. The descriptions indicate that for this proposal, competencies are universally at the lower levels of a knowledge taxonomy, largely confined to understanding, describing, and identifying. The competencies proposed by Long and Magerko are outlined in **Table 1**.

Table 1. AI Literacy Competency Framework

Competency	Description / learning outcomes
1. Recognizing AI	Distinguish between technological artefacts that use and do not use AI.
2. Understanding intelligence	Critically analyse and discuss features that make an entity 'intelligent'. Discuss differences between human, animal, and machine intelligence.
3. Interdisciplinarity	Recognize that there are many ways to think about and develop 'intelligent' machines. Identify a variety of technologies that use AI, including technology spanning cognitive systems, robotics and ML.
4. General vs narrow AI	Distinguish between general and narrow AI.
5. 5: AI strengths and weaknesses	Identify problem types that AI does/does not excel at. Determine when it is appropriate to use AI and when to leverage human skills.
6. Imagine future AI	Imagine possible future applications of AI and consider the effects of such applications on the world.
7. Representations	Understand what a knowledge representation is and describe some examples of knowledge representations.
8. Decision-making	Recognize and describe examples of how computers reason and make decisions.
9. ML steps	Understand the steps involved in machine learning and the practices and challenges that each step entails.
10. Human role in AI	Recognize that humans play an important role in programming, choosing models, and fine-tuning AI systems.
11. Data literacy	Understand basic data literacy concepts.
12. Learning from data	Recognize that computers often learn from data (including one's own data).
13. Critically interpreting data	Understand that data requires interpretation. Describe how the training examples provided in an initial dataset can affect the results of an algorithm.
14. Action and reaction	Understand that some AI systems have the ability to physically act on the world. This action can be directed by higher-level reasoning (e.g. walking along a planned path) or reactive impulses (e.g. jumping backwards to avoid a sensed obstacle).
15. Sensors	Understand what sensors are and that computers perceive the world using sensors. Identify sensors on a variety of devices. Recognize that different sensors support different types of representation and reasoning about the world.
16. Ethics	Identify and describe different perspectives on the key ethical issues surrounding AI: privacy, employment, misinformation, 'singularity',[11] decision-making, diversity, bias, transparency and accountability.
17. Programmability	Understand that agents are programmable.

Source: Long and Magerko, 2020

The design considerations proposed by Long and Magerko (2020) focus on pedagogical and learning methods, but also on social and interpersonal elements. Overall, they emphasize experiential learning and relevant material, an appreciation for cognitive demands and child development theory, and the positioning of AI within learner contexts. The 15 specific design considerations that the researchers present are:

1. **Explainability**: Include graphical visualizations, simulations, explanations of agents' decision-making

11 Describes the point at which AI becomes more intelligent than humans, and can be accompanied by concerns that AI would intentionally harm humans.

processes, or interactive demonstrations in order to aid learners' understanding of AI.

2. **Embodied interactions**: Design interventions in which individuals can act as or follow the agent, as a way of making sense of the agent's reasoning process. This may involve embodied simulations of algorithms and/or hands-on physical experimentation with AI technology.
3. **Contextualizing data**: Encourage learners to investigate who created the dataset, how the data was collected, and what the limitations of the dataset are. This may involve choosing datasets that are relevant to learners' lives, are low-dimensional and are 'messy' (i.e. not cleaned or neatly categorizable).
4. **Promote transparency**: Promote transparency in all aspects of AI design (i.e. eliminating black-box functionality, sharing creator intentions and funding/data sources, etc.).
5. **Unveil gradually**: To prevent cognitive overload, give users the option to inspect and learn about different system components; explain only a few components at a time; or introduce scaffolding that fades as the user learns more about the system's operations.
6. **Opportunities to program**: Provide ways for individuals to program and/or teach AI agents. Keep coding prerequisites to a minimum by focusing on visual/auditory elements and/or incorporating strategies like Parsons problems and fill-in-the-blank code.
7. **Milestones**: Consider how perceptions of AI are affected by developmental milestones (e.g. theory of mind development), age, and prior experience with technology.
8. **Critical Thinking**: Encourage learners to be critical consumers of AI technologies by questioning the intelligence and trustworthiness of AI applications.
9. **Identities, values and backgrounds**: Consider how learners' identities, values, and backgrounds affect their interest in and preconceptions of AI. Learning interventions that incorporate personal identity or cultural values may encourage their interest and motivation.
10. **Support for parents**: When designing for families, help parents scaffold their children's AI learning experiences.
11. **Social interaction**: Design AI learning experiences that foster social interaction and collaboration.
12. **Leverage learners' interests**: Exploit current issues, everyday experiences, or common pastimes like games or music when designing AI literacy interventions.
13. **Acknowledge preconceptions**: Allow for the fact that learners may have politicized or sensationalized preconceptions of AI from popular media, and consider how to respect, address, and expand on these ideas in learning interventions.
14. **New perspectives**: Introduce perspectives that are not as well-represented in popular media (e.g. less-publicized AI subfields, balanced discussions on the dangers and benefits of AI).
15. **Low barrier to entry**: Consider how to communicate AI concepts to learners who do not have extensive backgrounds in mathematics or computer science (e.g. by reducing the prerequisite knowledge/skills, relating AI to prior knowledge, and addressing learners' insecurities about their ability).

AI4K12: Five Big Ideas and K–12 AI Curriculum Guidelines

The AI4K12 Initiative was launched by the Association for the Advancement of Artificial Intelligence (AAAI), the Computer Science Teachers Association (CSTA), and AI4All in 2018 as a joint working group that seeks to develop national guidelines for teaching K–12 students about AI (AAAI, 2018).

This group brought together academics, researchers and teachers to work towards a comprehensive AI framework based on 'five big ideas': 1) computers perceive the world using sensors; 2) agents maintain representations of the world and use them for reasoning; 3) computers can learn from data; 4) intelligent agents require many types of knowledge to interact naturally with humans; and, at the very centre, 5) AI can impact society in both positive and negative ways. The 'Five Big Ideas in Artificial Intelligence' poster resource has been translated into 15 languages to date,[12] and formed at least part of the basis for the development of curricula in multiple contexts, including several of the curricula researched for this study.

The working group was convened to unpack each of these ideas into a curriculum framework divided into four parts, for grades K–2; 3–5; 6–8; and 9–12. To date, curriculum guidelines for the first three 'big ideas' have been drafted and are currently available for public comment.[13]

12 See https://ai4k12.org/resources/big-ideas-poster
13 See https://ai4k12.org/gradeband-progression-charts

In the guidelines, each 'big idea' is subdivided into learning concepts, which are further split into concept components. For example, the learning concepts, concept components and associated learning outcomes for 'Big Idea 1: Perception' are summarized in **Table 2**.

Table 2. 'Big Idea 1: Perception' concepts and learning outcomes

Learning concepts	Concept components	Learning outcome progression
Sensing	Living things	K–2: Identify human senses and sensory organs. 3–5: Compare human and animal perception. 6–8: Give examples of how humans combine information from multiple modalities. 9–12: N/A
	Computer sensors	K–2: Locate and identify sensors (camera, microphone) on computers, phones, robots, and other devices. 3–5: Illustrate how computer sensing differs from human sensing. 6–8: Give examples of how intelligent agents combine information from multiple sensors. 9–12: Describe the limitations and advantages of various types of computer sensors.
	Digital encoding	K–2: N/A 3–5: Explain how images are represented digitally in a computer. 6–8: Explain how sounds are represented digitally in a computer. 9–12: Explain how radar, lidar, GPS, and accelerometer data are represented.
Processing	Sensing vs perception	K–2: Give examples of intelligent vs non-intelligent machines and discuss what makes a machine intelligent. 3–5: Use a software tool such as a speech transcription or visual object recognition demo to exhibit machine perception, and explain why this is perception rather than mere sensing. 6–8: Give examples of different types of computer perception that can extract meaning from sensory signals. 9–12: Explain perception algorithms and how they are used in real-world applications.
	Feature extraction	K–2: Give examples of the features that one would look for if one wanted to recognize a certain class of objects or entities (e.g. cats) in an image. 3–5: Illustrate how face detection works by extracting facial features. 6–8: Illustrate the concept of feature extraction from images by simulating an edge detector. 9–12: Explain how features are extracted from waveforms and images.
	Abstraction pipeline: language	K–2: Describe the different sounds that make up one's spoken language, and for every vowel sound, give a word containing that sound. 3–5: Illustrate how sequences of sounds can be recognized as candidate words, even if some sounds are unclear. 6–8: Illustrate how sequences of words can be recognized as phrases, even if some of the words are unclear. 9–12: Illustrate the abstraction hierarchy for speech understanding, from waveforms to sentences.
	Abstraction pipeline: vision	K–2: Demonstrate figure/ground segmentation by identifying the foreground figures and the background in an image. 3–5: Illustrate how the outlines of partially occluded (blocked) objects in an image differ from the full shapes of the objects. 6–8: Describe how edge detectors can be composed to form more complex feature detectors, e.g. for letters or shapes. 9–12: Demonstrate how perceptual reasoning at a higher level of abstraction draws upon earlier, lower levels of abstraction.
Domain knowledge	Types of domain knowledge	K–2: Describe some things an intelligent agent must 'know' to make sense of a question. 3–5: Demonstrate how a text-to-speech system can resolve ambiguity using context, and how the error rate increases with ungrammatical inputs. 6–8: Classify a given image and then describe the kinds of knowledge a computer would need in order to understand scenes of that type. 9–12: Analyse one or more online image datasets. Describe the information that the datasets provide and how this can be used to extract domain knowledge for a computer vision system.
	Inclusivity	K–2: Discuss why intelligent agents need to understand other languages. 3–5: Discuss how domain knowledge must be broad enough for all the groups an application is intended to serve. 6–8: Describe how a vision system might show cultural bias if it lacked knowledge of objects not found in the culture of those who created it. 9–12: Describe some of the technical difficulties in making computer perception systems function well for diverse groups.

Source: AI4K12 (2020)

Each big idea is broken down in a similar manner with a concrete learning outcome pathway from early primary school to high school. In addition to these outcomes, the curriculum guidelines offer examples of the 'enduring knowledge' that students are expected to retain, for example: 'Sounds are digitally encoded

by sampling the waveform at discrete points (typically several thousand samples per second), yielding a series of numbers' or 'The spoken language hierarchy is: waveforms ➡ articulatory gestures➡ sounds ➡ morphemes ➡ words ➡ phrases ➡ sentences.' Sometimes the learning outcomes and enduring knowledge are further unpacked, as was this second example: 'To go from noisy, ambiguous signals to meaning requires recognizing structure and applying domain knowledge at multiple levels of abstraction. A classic example: the sentences "How to recognize speech" and "How to wreck a nice beach" are virtually identical at the waveform level.'

Occasionally, activities are suggested. For instance, to explain decision trees at the grade 3–5 level, 'the "guess the animal" game, troubleshooting problems, and the Pasta Land activity' are recommended.

The big ideas are mutually reinforcing. For example, 'Big Idea 3' leverages the knowledge from sensing components to facilitate a discussion of differences in how people and computers learn. Similarly, it builds on the knowledge of processing components to equip learners to label a dataset for machine learning, train classifiers and engage AI concepts such as decision trees, neural networks, supervised learning, unsupervised learning, and reinforcement learning.

The Machine Learning Education Framework

Although it never mentions competence-based education, the Machine Learning Education Framework (Lao, 2020) follows the well-known CBE framework of knowledge, skills and attitudes (which have in other contexts included items such as abilities and/or values) (Brewer and Comyn, 2015; CANTA, 2014; European Parliament and Council of the European Union, 2006). CBE has in the past been criticized by some for its lack of attention to the meaning of the task for students and a reductionist view of competence which, while firmly rooted in the context of performance, is less sensitive to individual factors like prior experience and the flexibility to tap into external resources, e.g. the knowledge of teammates (Rutayuga, 2014). However, the gradual integration of theories such as constructivism and experiential learning (Brunner, 1990; Kolb, 2015; Piaget, 1972; Williams, 2017) has resulted in a competence-based framework that focuses on 'head, heart and hands', in which the 'head' represents the cognitive domain (what you know about it), the 'heart' represents the affective domain (why it matters) and 'hands' represent the psychomotor domain (what you can do with it) (Gazibara, 2013; Singleton, 2015; Sipos et al., 2008). This integration has also expanded the concept of competence to include social and emotional skills (European Parliament and Council of the European Union, 2006; Mulder, 2007).

In addition, Lao (2020) draws on:

- theories of constructionism, or the idea that learning is enhanced when undertaken through the construction of an item that has personal meaning for the students;
- computational thinking, a proposed reframing of familiar competence concepts to apply concretely to the programming world: technical *concepts*, programming *practices,* and *perspectives* on an individual's relationships with technology;
- a model for understanding the learning outcomes for computational thinking lessons, divided into abstraction, or the ability to apply concepts to new use cases; automation, or utilizing a computer to increase efficiency in repeated tasks; and analysis, or reflection on a student's assumptions and methods of implementation (Lee et al., 2011).
- Use-Modify-Create (UMC), a tiered progression often employed in computational thinking lessons, in which students first engage with existing software, and then modify it to fit new needs, and finally create new software (Lee et al., 2011).

The Machine Learning Education Framework (outlined in **Table 3**) consists of six 'minimally required courses for ML-engaged citizens', and is targeted to a 'tinker/consumer' audience (Lao, 2020, p. 61). In her framework, Lao makes the argument that understanding bias and the social implications of AI are fundamental requirements for all skills.

Table 3. The Machine Learning Education Framework with learning outcomes and definitions

Knowledge	
1. General ML knowledge*	Know what machine learning is (and is not). Understand the entire pipeline of the creation of ML systems.
2. Knowledge of ML methods	Identify when to use a range of ML methods across the breadth of the field (e.g. k-nearest neighbours, CARTs or decision trees, neural networks, ensemble methods). Understand how different methods work.
3. Bias in ML systems*	Understand that systems can be biased, and the different levels and ways in which bias can be introduced.
4. Societal implications of AI*	Understand that ML systems can have widespread positive and negative impacts. Consider the ethical, cultural and social implications of what they do.
Skills	
1. ML problem scoping	Determine which problems can and should be solved by ML.
2. ML project planning	Plan a solution which is sensitive to both technical and contextual considerations.
3. Creating ML artefacts	Use tools to create appropriate artefacts.
4. Analysis of ML design interactions and results*	Describe the explicit and implicit design intentions of an ML system. Critically analyse the intentions against how the system can and should be used.
5. ML advocacy*	Critically discuss ML policies, products and education.
6. Independent out-of-class learning	Students seek learning experiences outside the classroom.
Attitudes	
1. Interest	Students are engaged and motivated to study the topic.
2. Identity and community	Students contribute to and learn from a community of peers and/or broader online communities who are interested in ML.
3. Self-efficacy	Students are empowered to build new, meaningful things.
4. Persistence	Students continue and expand their engagement with ML.

**The starred items are the six required courses outlined in the framework.*

Source: Lao, 2020

Lao (2020) also presents a rubric for evaluating ML learning programmes against this framework, setting up the basis for a set of standards at the exit level which could be built upon. For example, the four 'top scores' in the rubric for the four learning outcomes under 'Knowledge' are:

1. **General knowledge**: Graduates of this course can give a precise definition of machine learning and provide a detailed description of the steps of the ML pipeline with technical and socio-ethical considerations for each step.
2. **Knowledge of ML methods**: Graduates of this course are able to accurately discern when to use a range of machine learning methods across the breadth of the field. They are able to describe core technical concepts of these methods and comfortably use/implement them in appropriate applications. (Lao then lists her views on appropriate methods for different educational levels:
   - **High school and above**: K-nearest neighbours, CART/DT, regression, convolutional neural networks; unsupervised methods such as k-means clustering, principal component analysis, GANs, and embeddings; RNNs/LSTMs; reinforcement learning; transfer learning; and ensemble methods.
   - **Primary and middle school**: Engage applications that allow students to complete specific tasks using ML, e.g. exploiting neural network and GAN applications to create art or music, or deploying reinforcement learning to play games, etc.)
3. **Bias**: Graduates of this course are able to describe how ML systems may come to be unpredictably biased against specific groups throughout each step of the ML pipeline. They can critically incorporate the practices of ethical thinking and design in their own work.
4. **Social implications**: Graduates of this course recognize that it is necessary for the creators of ML technologies to consider the societal implications of their work. They are able to apply ethical and cultural perspectives and concepts to the analysis of ML artefacts in comprehensive, interrelational and sensitive ways (i.e. considering privacy, security, the potential for abuse, and the balance of benefits and harm; and assessing ethnographic reception and disparate impacts using tools such as stakeholder analyses, ethical matrices and model cards).

Methodology

Data collection

Two surveys were distributed, the first to representatives of 193 UNESCO Member States and the second to over 10,000 private- and third-sector actors.[14] The surveys asked the respondents to report on AI curricula for students in K–12 general education. Appendix A provides the questions in the survey sent to the representatives of Member States. It was modified only very slightly for the private- and third-sector actors.

After the surveys were returned, the team emailed additional questions on learning outcomes, implementation and preparation to the respondents who had indicated that they did have AI curricula at some stage of development.

In addition, semi-structured key informant interviews were held with Member State representatives, non-profit leaders and developers, academics and industry professionals to gain further clarity on the curricula and their deployment in schools. Interviews probed the motivations for developing the AI curricula, and the reasons for their decisions around implementation methods and pedagogies.

Finally, a mapping exercise was undertaken for those curricula which had been drafted or published and were available for review. The exercise focused on the learning outcomes stated within each curriculum. Where possible, associated textbooks or materials were also reviewed to gain a further understanding of the content covered by the curriculum.

Criteria for selecting government-endorsed AI curricula

This study is focused on government-endorsed curricula within general K–12 education. The results include only the curricula that have been, or are in the process of being, approved by national or local governments. As stated earlier, 'AI curricula' in this study refers to structured programmes of learning that cover topics in the field of AI and engage with AI-related learning outcomes.

Of the 193 Member States contacted through the official UNESCO channels of correspondence, a total of 51 responded, indicating at least a general interest in the topic. Among them, 29 countries and one territory completed the full survey.

- Representatives from 10 countries reported no AI curricula in their country. These are: Bahrain, Canada, Colombia, Costa Rica, Estonia, Guinea, Macedonia, the Maldives, Singapore, and the Ukraine.
- Representatives from 20 countries and one territory responded that they were aware of at least one AI curriculum that was developed and endorsed by government or is under development. These are: Algeria, Armenia, Austria, Belgium, Canada (Yukon Territory), France, Germany, Jordan, Republic of Korea, Kuwait, Lao People's Democratic Republic, Peru, Portugal, Qatar, the Republic of Bulgaria, Saudi Arabia, Serbia, Slovenia, Syria, and the United Arab Emirates.

In addition, a total of 31 NGOs, academics and industry partners responded to the non-governmental survey and indicated that they had an AI curriculum.

All Member State representatives and organizations reported having an AI curriculum were contacted with follow-up questions via email and asked to provide any available curriculum documents.

During the course of these follow-up emails and the curriculum mapping exercises, it was found that some of the reported curricula did not to meet the stringent criteria set out for inclusion in this study. Curricula were excluded from further analysis if they did not have AI-specific learning outcomes, did not cover ordinary K–12 education (e.g. were focused on TVET), were not endorsed by the government at the national or regional level, and/or did not provide enough information to analyse.

14 These actors were sourced through a list of key organizations in the field of ICT in education accumulated by UNESCO over the course of organizing nine editions of the Mobile Learning Week from 2011 to 2020.

List of government-endorsed AI curricula

Curricula are categorized as 'governmental' if they were provided in response to the survey distributed to UNESCO Member States and were developed by or under the directive of governmental agencies. In order to be eligible for analysis, the survey and interview responses had to provide clear, consistent and meaningful information on the curriculum.

After applying the selection criteria to all of the data from the governmental and non-governmental surveys, it was found that:

- 11 Member States have developed, endorsed and implemented AI curricula.
- The Yukon Territory of Canada has developed and implemented a curriculum entitled Applied Design, Skills, and Technologies, which has been locally rather than nationally endorsed.

Table 4. K–12 AI curricula, endorsed and implemented by governments

Country/ region	Curriculum title	Curriculum developer[15]	Educational levels		
			Primary	Middle	High
Armenia	Curriculum of ICT	Government		X	X
Austria	Data Science and Artificial Intelligence	Federal Ministry of Education, Science and Research			X
Belgium	IT Repository	*Fédération Wallonie-Bruxelles* (French-speaking Community of Belgium)			X
China	AI curriculum embedded in the Information Science and Technology curriculum	The Ministry of Education of the People's Republic of China	X	X	X
India	Atal Tinker Labs AI modules	Atal Tinker Labs, Atal Innovation Mission, NITI Aayoag		X	X
Republic of Korea	'AI Mathematics' under the Mathematics Subject Group for high schools	Korea Foundation for the Advancement of Science and Creativity			X
	'AI Basics' under Technology Home Economics Subject Group for high schools	Korea Foundation for the Advancement of Science and Creativity			X
Kuwait	Standards curriculum	Curricula technical guidance experts and teachers	X	X	
Portugal	Information and Communication Technologies	State school teachers of ICT and Mathematics	X	X	X
Qatar	Computing and Information Technology	Binary Logic, Ministry of Education and Higher Education	X	X	X
	Computing and Information Technology (High Tech Track)	Binary Logic, Ministry of Education and Higher Education			X
Serbia	Informatics and programming – Grade 8	Ministry of Education working group		X	
	Modern technologies in gymnasiums – Grade 3 and 4	Ministry of Education working group			X
United Arab Emirates	AI curriculum embedded under the Technology Subject Framework	Ministry of Education	X	X	X

Source: UNESCO (2021*b*)

In addition to the curricula being implemented, those that are in development and will likely be endorsed by the governmental agencies were also analysed. As shown in **Table 5**, these include an additional three AI curricula from Serbia and one each from four more countries (Germany, Jordan, the Republic of Bulgaria and Saudi Arabia).

15 This column shows the responses as they appeared in the completed surveys.

Table 5. Governmental K–12 AI curricula in development

Country/ region	Curriculum title	Curriculum developer	Educational levels		
			Primary	Middle	High
Germany	1. Identifying and Formulating Algorithms [*Algorithmen erkennen und formulieren*]	Standing Conference of the Ministers of Education and Cultural Affairs of the Länder	X	X	X
Jordan	2. Digital Skills	National Center for Curriculum Development		X	X
Bulgaria	3. Computer Modelling, Information Technology and Informatics	Expert groups (academia, teachers, education experts)	X	X	X
Saudi Arabia	4. Digital Skills	Binary Logic and Tatweer Co.	X	X	X
Serbia	5. Technique and Technology	Ministry of Education working group		X	
	6. AI in gymnasiums	Ministry of Education working group			X
	7. AI in all high schools	Ministry of Education working group			X

Source: UNESCO (2021*b*)

Non-governmental curricula were included in the study if they covered AI learning outcomes and were at some stage of implementation in cooperation with at least one local government. However, these curricula have not been confirmed as officially endorsed by governmental agencies, and are included only as non-governmental benchmarks.

Some of these developers have undertaken other work related to the listed curricula which was also examined for the curriculum mapping. These include a curriculum adaptation entitled 'IBM-CBSE AI Curriculum for Grade XI & XII' and the Microsoft series of textbooks called *Artificial Intelligence, Data Analytics* and *Machine Learning*, both designed for use in India; and the Microsoft Computer Science Curriculum Toolkit.

Table 6. Non-governmental AI curricula included in the study as benchmarks

Country/ region	Curriculum title(s)	Curriculum developer	Educational levels		
			Primary	Middle	High
International	1. IBM EdTech Youth Challenge	IBM		X	X
	2. AI Youth Skills	Microsoft		X	X
	3. Global AI Readiness Program (High Tech Track)	Intel		X	X
	4. Global AI Readiness Program (General Track)	Intel		X	X
United States	5. DAILy Curriculum	MIT		X	X

Source: UNESCO (2021*b*)

Limitations to the survey analysis

As noted earlier, this analysis does not capture all of the activities related to developing AI competencies for school children, and does not even encompass all of the available information on governmental AI curricula. A wide range of curricula are outside the scope of this study. For example, three curricula were submitted from Austria, but two operated in the TVET sector, which is not covered here. A number of for-profit providers supply training on their proprietary technology, and many AI-training programmes are offered by NGOs through non-formal learning channels like independent study; none of these were analysed.

Other limitations include the following:

- **Some government-endorsed AI curricula might have been missed.** The survey was sent out to all 193 Member States, but it is possible that some countries which do have AI curricula did not respond.
- **There are gaps in the data**. Some of the data sought, particularly around the number of schools and learners, were not available for many curricula, which either do not track these or are not authorized to release them.
- **The future relevance could be questionable.** The mapping is time-bound, as many curricula are still in development and may be further revised. This dataset only provides a snapshot of activities in the non-governmental and private sector, and may be of limited utility in the future.

Key findings of the analysis of government-endorsed AI curricula

The following five sections present the results of the analysis:

1. The section on **curriculum development and endorsement mechanisms** addresses the mandate, motivation and means of endorsement for the AI curricula.
2. The section on **curriculum integration and management** includes approaches to incorporating AI curricula into education systems, including time allocations in terms of percentages and total hours and the preparation of essential conditions for supporting AI curricula.
3. The section on **curriculum content** outlines the time allocations for topic areas in three main categories of content, namely AI foundations; ethics and social impact; and understanding, using and developing AI tools.
4. This section presents the **learning outcomes** of mapped AI curricula defined under the competence areas of knowledge, skills and values.
5. The section on **curriculum implementation** summarizes the main strategies for teacher training and support, preparation of the required learning tools and environments, and suggested pedagogies.

Curriculum development and endorsement

As listed above, 14 AI curricula were endorsed and mandated for use in schools by governmental agencies in 11 countries, while 7 curricula in 5 countries are still in development. Only Serbia has both endorsed curricula and curricula still in development. A further two curricula were endorsed at the local level: the Applied Design, Skills, and Technologies curriculum from the Yukon Territory in Canada, and the MIT DAILy Curriculum in the United States. In some parts of the analysis, the four private-sector, non-governmental AI curricula were also included as benchmarks.

AI curriculum development and endorsement mechanisms

- **Centralized government-led approach**

The majority of these curricula were developed by national public agencies and endorsed through a centralized government-led approach, at times with the participation of or in collaboration with key stakeholders. For example, in the Republic of Korea, development was undertaken by experts under a government directive; and in China, Kuwait, and the Republic of Bulgaria, development included teachers as well as academics and experts.

- **Government-commissioned private provision**

A second approach was government-commissioned private provision. In Saudi Arabia and Qatar, companies were commissioned by the government to develop the national curriculum. The Saudi Arabian representative commented that:

> "New technologies emerge every day, and application features are updated frequently. Therefore, we choose to work with a quality private company that has a strong reputation for ICT curriculum construction and incorporates the latest technologies and IT applications.

- **Government-directed decentralized approach**

The third approach to development and endorsement was a government-directed decentralized approach. In Belgium, a parliamentary mandate created standards which were then adopted by networks of schools. These networks determine aspects such as the technologies and pedagogies to be used. A similar approach is seen in Germany, where a national mandate and standards are further developed by local or provincial governments into a curriculum for implementation in schools.

- **Private-sector-driven non-governmental AI curricula**

Finally, some curricula are non-governmental and driven by private sector actors. They may be adopted as-is by schools or adapted by local experts when they develop curricula for governmental agencies. These curricula aim for a degree of flexibility so that they can be incorporated into various government frameworks and requirements, and further customization is also undertaken for specific country contexts. An important part of the development and endorsement of these curricula is validation, both nationally and internationally. Intel's representative remarked that:

> "We had the curriculum extensively validated by countries...We created a global pool of validator experts and gave them the content to modify and make recommendations. When we started implementing it in 2019 and 2020, we did an extensive evaluation.

But no evidence has shown that these private-sector-driven curricula have been endorsed as governmental AI curricula. In examples of this approach, industry or academic stakeholders including IBM, Intel, Microsoft and MIT have produced their own curricula and resources in consultation with experts and teachers.

Vision and motivations for developing AI curricula

The interview respondents indicated two significant rationales for the development of AI curricula: to improve capacity and respond to the skills needed by the labour market, and to ensure that students graduate with the skills necessary for everyday interactions in social and political life. The extent to which these considerations were emphasized differed widely, though. For example, one country indicated they were not at all concerned with labour market skills, while others cited this as the primary consideration.

The goal of developing skills for the labour market reflected an understanding of the shifting needs of the technology sector and the wider world of work. For most but not all countries, this was linked to a desire to develop an internationally competitive workforce. Corporate developers also mentioned this as a strong motivation for including the development of AI training courses for students in their corporate social responsibility activities.

The second rationale was associated with an understanding of AI as a driver of social as well as economic transformation, and a desire to foster general knowledge about AI and its functions and uses in society among students. Several survey respondents noted that AI is already embedded in a range of everyday interpersonal interactions, and felt citizens should recognize AI in their environments, understand its benefits and potential challenges, and be empowered to advocate for safe, beneficial and transparent AI technologies. This is exemplified in the following three comments, which were contributed by the representatives from Portugal, Austria and Jordan respectively:

> "We have a clear vision of the impact of technology in the future, and the need for a workforce and citizens who relate to technology in a healthy way on a daily basis. This includes the concepts, awareness, and skills to improve these areas, work with machines, and see robotics as complementary to society. This is the big picture.

> Artificial intelligence is seen as a transversal issue that has the potential to disruptively change key areas and concepts of life. Therefore, it is not only the expertise of specialists and developers that is of great importance in the consideration of AI in education, but also general knowledge about the basics for all people to enable them to lead a safe and self-determined life in a world shaped by AI.

> The plan is to develop a digital skills curriculum appropriate to global developments and the expected digital transformation, and also attain the worldwide digital competencies as relevant to our context.

Pilot testing and evaluation of AI curricula

The following governmental AI curricula have been implemented and evaluated: Computer Modelling, Information Technology and Informatics, Republic of Bulgaria; Information Science and Technology, China; MIT DAILy Curriculum; Serbia's Informatics and Programming, Modern Technologies, and Technique and Technology; and the Technology Subject Framework implemented in the UAE.

Additionally, the implementation of the following non-governmental AI curricula have been evaluated: IBM EdTech Youth Challenge; both versions of the Intel AI for Youth: Global AI Readiness Program; and Microsoft AI Youth Skills.

Some of the curricula were revised based on the evaluation, including China's, the UAE's, IBM's, Intel's (both versions), Microsoft's, and MIT's. A few are still being piloted and may be further revised, namely the one from Bulgaria, the MIT DAILy Curriculum, and Serbia's Technique and Technology.

Common evaluation methodologies included:

- **Expert reviews of the curriculum**. For example, in the UAE, the curriculum was shared with different social stakeholders including academics and AI specialists. Cross-disciplinary reviews were conducted by experts in psychology and education.
- **Research conducted by developers**. Methodologies included testing learners and carrying out interviews and surveys with teachers and representatives of regional and/or national administrative departments. Information was gathered on learning outcomes, the perceived usefulness of the curriculum, and challenges in implementation.
- **External evaluation**. Some governments commissioned external evaluations of the curriculum and/or its outcomes. For example, the Republic of Bulgaria commissioned a national external assessment which measured the digital competencies of learners.

Few of these reviews or evaluations are published. A key point surfaced by the interviews was that AI curricula should be coordinated with the mathematics curriculum and the classroom requirements. For example, a curriculum review in China determined that the level of requirements for the Information Science and Technology curriculum was above that of mathematics and science subjects, so the expectations had to be revised. The curriculum also had to cater for a wide range of contexts, and the unique opportunities and challenges of both urban and rural settings.

A pilot study of one part of the MIT DAILy Curriculum found that according to the teachers, the students seemed more engaged than usual, and 'what is and is not AI' was the key to students' understanding. Some teachers found the ethics modules odd and confusing, but others embraced them. The use of hardware was perceived to be the most difficult component of the pilot to manage and required strong teacher investment and attention, particularly when the equipment did not work properly, although this helped students to learn important skills like resiliency (Williams et al., 2021).

Example: Qatar curriculum development foundations and principles[16]

Qatar Vision 2030[17] acknowledges technology as a key factor for a modern knowledge-based economy, and the Qatar National Curriculum Framework (QNCF) defines IT as a major school subject in grades 1-12 which aims to 'support children's learning by offering beneficial opportunities in the areas of logic and mathematical thinking, language and communication, emergent literacy and creativity'.

To support these national policies, standards were created as a foundation of the national Computing and Information Technology curriculum through a collaboration between industry experts, the Qatar Ministry of Education and Higher Education's ICT experts team, and ICT supervisors at primary, preparatory and secondary schools. The standards were reviewed by the computer science experts and curriculum development experts of three Qatari higher education institutions. The curricula developed under the standards include a universal compulsory track for all grade levels and an elective 'high-tech' track for senior high schools. Both tracks include AI learning outcomes related to algorithms, programming, ethics and social impact, and understanding and using AI tools and technologies. Students in the high-tech track also engage in developing AI technologies.

The intention is to review the standards periodically to ensure that they capture current technologies and trends in computer science and IT. Ensuring the curriculum is not dependent on specific technologies, platforms or applications is another step toward guaranteeing the sustainability of the standards over time. The curriculum framework further suggests incorporating teacher feedback and international best practice reviews to make additional adjustments that bolster its effectiveness.

The development of Qatar's Computing and Information Technology curriculum standards was guided by five main principles:

1. Alignment to a national curriculum framework, including the 'competencies, values, aims, principles and cross-cutting issues', with competencies

16 Information in this section is sourced from the *Qatar Computing and Information Technology Curriculum 2018* produced by the country's Ministry of Education and Higher Education. It can be provided on request via email.
17 See https://www.gco.gov.qa/en/about-qatar/national-vision2030

explicitly linked to national standards. The curriculum covers knowledge, skills and attitudes with a focus on:

- Computer science principles and practices, namely programming, robotics and AI;
- Digital literacy, defined in the curriculum as the 'creative and productive use and application of computer systems', including aspects of ethics, intellectual property and e-safety;
- The promotion of soft skills, in this case as defined by the American Association of School Librarians: collaboration, communication, teamwork, critical thinking, problem-solving and decision-making.

2. 'Spiral' development, so that concepts reappear at different grade levels with increasing difficulty and greater depth with each iteration. At the same time, the skills development must be coherent and efficient, so that both needless repetition and academic gaps are eliminated.
3. Student-centred learning and hands-on project-based approaches. Computational thinking is a core element, and students are expected to leverage the process of abstraction, automation and analysis as a new approach to problem-solving, beginning with an understanding of the basic principles of computational thinking in grade 1.
4. Computing language, hardware and platform independence, meaning the curriculum does not rely on a particular provider, brand or programming language but seeks to cover a wide range of tools and technologies that students encounter in real life.

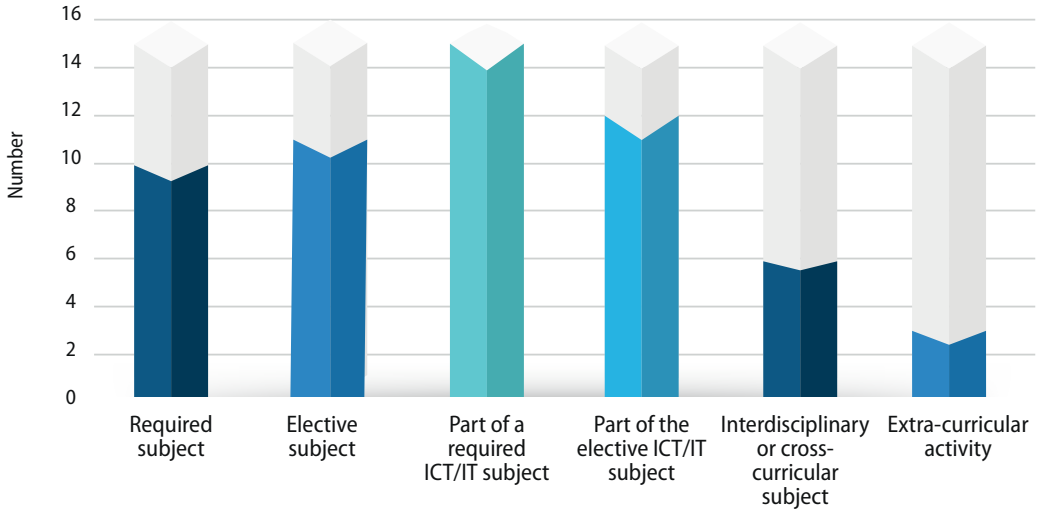
Curriculum integration and management

Curricula are integrated into existing education systems through a number of different models:

- **Discrete AI curricula** are developed in an independent subject category within the national or local curriculum framework. These curricula have their own time allocations, textbooks and resources, as in the case of China's Foundations of AI under Information Science and Technology for grades 10 to 12.
- **Embedded AI curricula** are developed and contained within other subject categories in the national or local curriculum framework. AI most commonly becomes a topic within ICT or computer science but may alternatively be part of language, mathematics, science or engineering (see **Figure 1**). In the Republic of Korea, two elective AI subjects have been developed, one falling within the mathematics subject group and the other in technology and home economics. Curricula can also be designed to be embedded flexibly into any subject depending on teacher capacity and interest. This is the case for the MIT DAILy Curriculum.
- **Interdisciplinary AI curricula** are implemented in systems with particular mandates for cross-subject work and associated time. These curricula target AI learning outcomes through project-based learning involving multiple subject areas. An example is seen in Portugal's curriculum frameworks, which feature 'autonomous curriculum domains', or projects that must engage two or three disciplines in an interdisciplinary approach. In the UAE, AI is integrated into a range of subjects including ICT, science, maths, language, social studies and moral education.
- **Multiple-modality AI curricula** have core requirements which are implemented during school time and supported by traditional resources such as facilitator guides and textbooks, but also leverage informal learning opportunities such as out-of-school resource networks and national or international competitions. An example of such a curriculum is the IBM-CBSE AI Curriculum for Grade XI & XII, which provides a gradual transition from guided to independent learning and links to competitions and industry mentorship.
- **Flexible AI curricula** can be implemented through one or more integration mechanisms at the discretion of regions, school networks or individual schools. Examples include the ATL AI modules curriculum in India, which can be embedded, interdisciplinary or delivered through out-of-school models such as extracurricular activities; and Digital Skills in Saudi Arabia, which can be implemented as either a discrete or embedded curriculum. For some curricula, the embedding mechanisms are at the discretion of regions, schools or networks. These include the French-speaking Belgium's IT Repository (2nd and 3rd degree technical transition), and Germany's *Algorithmen erkennen und formulieren* [Identifying and Formulating Algorithms] curriculum.

Curricula can also be compulsory, meaning all students must participate; or elective, meaning that students choose to participate. In some curricula, such as China's Information Science and Technology, certain modules are compulsory and others are elective.

Figure 1. Number of AI curricula by integration type (n = 27, multiple responses possible)



Source: UNESCO (2021*b*)

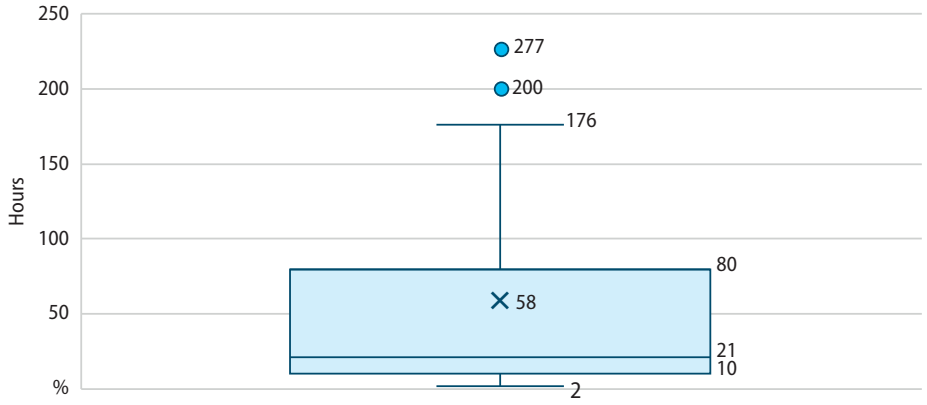
One important point raised was that AI curricula, and ICT curricula more broadly, should not be heavily reliant on one particular technology, as it is important to diversify the skills being developed across different platforms and providers. Some countries such as Austria and China emphasize an 'agnostic approach' to technology, which means that the curriculum is not linked to any particular brands, devices or programming languages. These curricula therefore aim to ensure (i) that teacher training is firmly rooted in theory, ensuring an understanding of underlying principles that can be applied across a range of technologies; and (ii) if particular hardware or software is used, teachers and learners are introduced to multiple choices and be engaged with different providers of AI tools.

Allocation of curriculum hours

Survey respondents were asked to provide the total number of learning hours for each of four grade levels: early primary, covering grades K-2; late primary, covering grade 3 to the end of primary school; middle school, covering grades 7 to 9 for most countries; and senior or high school, covering grades 10 to 12 for most countries.

The total time allocations for curricula ranged from two to 924 hours, spread over between one and twelve grade levels. A boxplot[18] of the time commitment per grade (see **Figure 2**) shows that the allocations vary widely.

Figure 2. Time allocation per year of AI curricula, n = 22



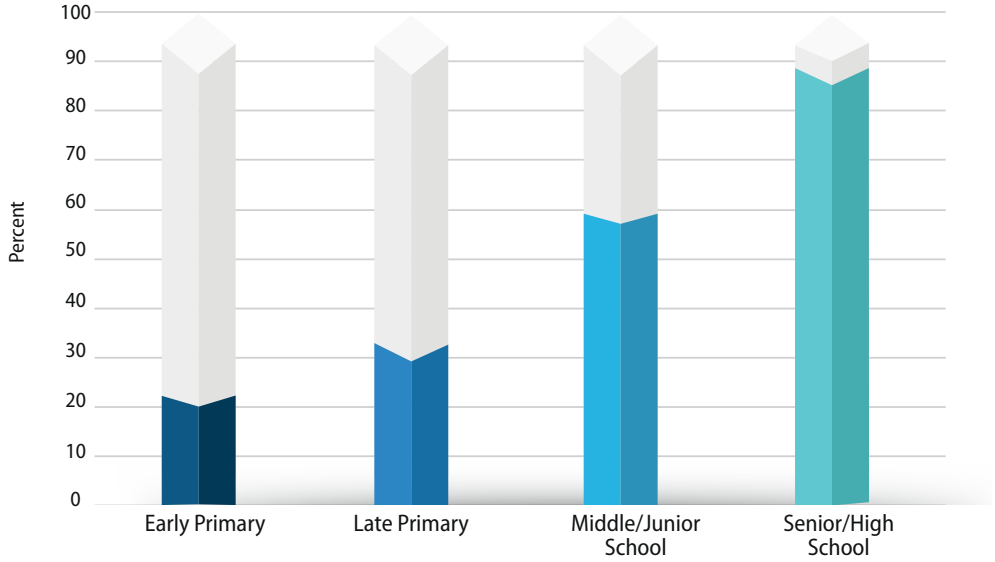
Source: UNESCO (2021*b*)

Two outliers, the Computing and Information Technology (High Tech Track) curriculum in Qatar and the IT Repository curriculum in Belgium average more than 200 hours per year. The average of 58 hours is more than twice as high as the median of 21 hours, revealing that there is a cluster of curricula which require relatively few hours of engagement with AI. In fact, five of the 22 curricula which provided time allocations require fewer than 5 hours of AI study per year, while five require 150 hours or more. Those demanding 150+ were either industry-developed curricula (two of the five) or high-technology elective tracks (also two of the five). Those requiring few hours of AI study were all embedded within other subjects.

Curricula were most likely to target senior or high school learners, and the proportion of curricula engaging each educational level increases steadily from early primary to the upper grades (see **Figure 3**).

18 Boxplots show the distribution of data including the minimum value, first quartile value, median value, third quartile value and maximum value. The mean value is displayed as an 'X', and outliers appear as dots above the boxplot.

Figure 3. Per cent of curricula engaging each grade level (n = 27)



Source: UNESCO (2021*b*)

The total hour commitment for curricula per grade level ranged from 1 to 680 hours. In grades K-2, AI was most likely to be integrated into other subjects and have no specific time allocation. Only Qatar's Computing and Information Technology dedicated a specific time allocation to K-2, 100 total hours. Across grades 3 to 6, an average of 156 hours was reported. The average time commitment as a whole for middle school (grades 7–9) was 109 hours, and for high schools (grades 10–12) the average was 153.5 hours. The average hours per grade were relatively static in K–9: 33.3 hours in grades K–2; 39 in grades 3–6; and 36.3 in grades 7–9. In high schools, the average time commitment per grade increases to 51.2 hours.

Essential conditions for supporting AI curricula

Survey respondents were asked how essential conditions were planned and prepared to support the design and implementation of the AI curriculum. The seven options that were presented in the questionnaire are outlined in **Table 7**. Multiple responses were possible, and a free-response option was also provided.

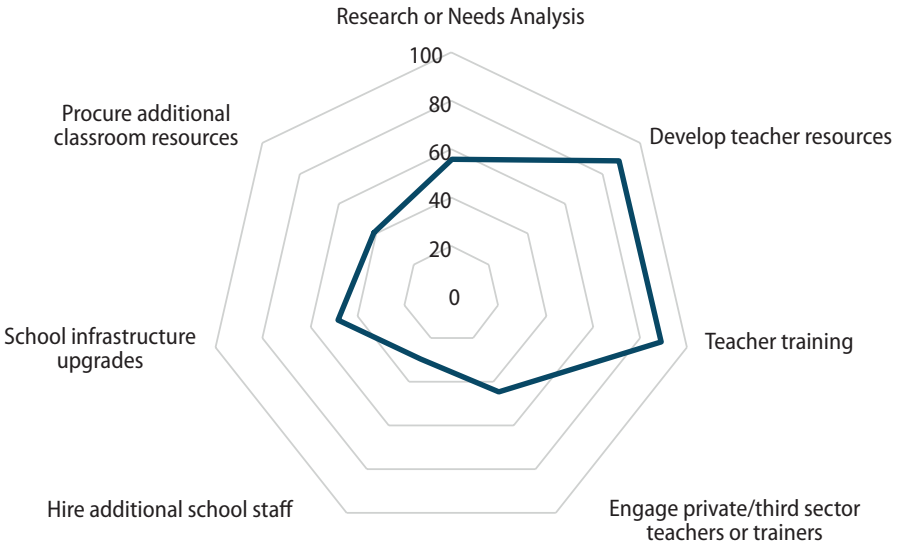
Table 7. Essential conditions for supporting AI curricula

Response options	Comment
Research or a needs analysis	Referred only to research or a needs analysis related to the implementation of the curriculum.
Development of resources for teachers	Textbooks and lesson plans were given as examples.
Teacher training	Respondents were asked about training specific to the AI curriculum and the resources facilitating it.
Hiring of additional staff/capacity	Referred to the recruitment of more paid teachers to implement the curriculum.
Engagement of the private or third sector	Rather or in addition to extra school staff, some countries engaged private or third-sector organizations as part-time trainers in or for schools.
Infrastructure upgrades at schools	Referred to the provision of hardware and/or internet connections for schools in relation to the AI curriculum. This includes items such as computer labs and servers.
Procurement of additional resources for schools or classrooms	Buying in classroom kits, coding resources, AI tools, etc.

Source: UNESCO (2021*b*)

The responses show that implementing an AI curriculum requires a range of adjustments to the resources and human capacity of education systems (see **Figure 4**). A majority of curricula were supported through the development of teachers' resources and training (89 per cent); 15 (56 per cent) through preliminary research or a needs analysis; 13 (48 per cent) through investment in school infrastructure upgrades; 12 (44 per cent) through engagement of the private or third sector; and 11 (41 per cent) through procuring additional resources for classrooms. The area emphasized the least was hiring additional school staff to implement the curriculum, but this was still a notable activity reported for 8 of the AI curricula included in this study (30 per cent).

Figure 4. Support for implementation undertaken



Source: UNESCO (2021*b*)

Example: The introduction of AI by the CBSE in India[19]

In 2019, India's Central Board of Secondary Education (CBSE) announced AI as an optional subject in the more than 22,000 schools under its jurisdiction, with a goal of ensuring that future citizens of India understand AI and are able to deploy it to address local and global problems. The curriculum focuses on 'learning through doing' and provides opportunities for students to learn AI by using it to build solutions to community challenges (CBSE, 2020).

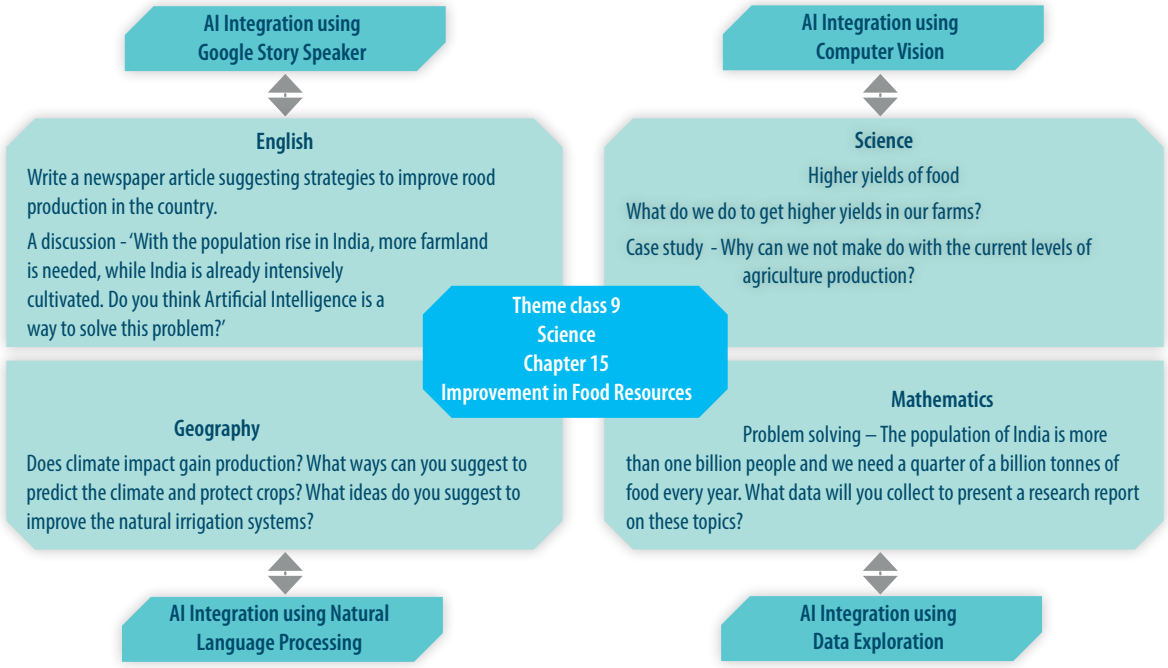
In support of the curriculum, the CBSE partnered with industry providers including IBM, Intel and Microsoft to develop training and support materials and content. NGOs also support the delivery of the curriculum.[20] To prepare for implementation, teacher and mentor training, and materials including facilitator guides, multi-disciplinary lesson plans and textbooks were created for grades 8–12. The CBSE also pursued a number of events with the overall aim of 'smoothing the integration of AI into schools'. These included competitions, virtual symposiums to give youth opportunities to explore AI technologies, and three-day 'AI-thon' camps where students execute a project design and prototype cycle using AI to solve an identified community challenge. More than 10,000 teachers and 120,000 students have been trained in AI through various partnership activities like these.

The AI curriculum is integrated as an elective or interdisciplinary subject in self-selected schools. The CBSE circulates an invitation to all schools to participate in this curriculum, and school administrators submit an application to the CBSE in response to the opportunity. Schools then select teachers for training, plan for AI to be included in the school timetable, and strategize around the interdisciplinary integration of AI based on common themes, such as 'improvement in food resources', the example in **Figure 5** (CBSE and Intel, 2019).

19 Sourced from: *CBSE Artificial Intelligence* (Ministry of Education, India, 2020); *Artificial Intelligence Curriculum, Class 9 Facilitator Handbook* (CBSE and Intel, 2019); and interviews with and presentations from representatives of IBM, Intel, the 1M1B Foundation and Microsoft. Note that this information may not represent the official views of the Government of India.

20 For example, 1M1B supports the implementation of the AI Youth Skills curriculum in partnership with CBSE and IBM. See https://www.youtube.com/watch?v=wKI5pghCIFY

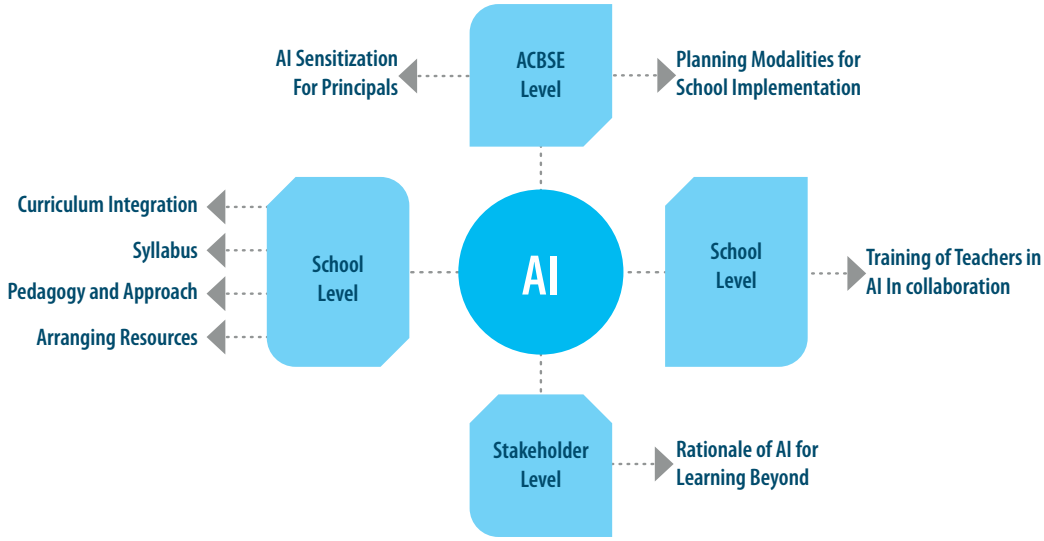
Figure 5. Thematic approach to the interdisciplinary integration of AI into the curriculum



Source: CBSE and Intel (2019)

At the school level, teacher training is facilitated by industry and/or implementation partners using bespoke courses and materials. Various providers such as IBM and Microsoft have developed textbooks in line with the CBSE curriculum aims. The curriculum integration, syllabus, pedagogy, approach, and procurement of necessary resources are also managed at the institutional level. Moreover, schools are expected to engage stakeholders, especially students and parents, to ensure they understand the rationale and aims behind the integration of AI into the curriculum. **Figure 6** outlines the relationship between the CBSE, schools and stakeholders.

Figure 6. AI implementation actors and procedures



Source: CBSE and Intel (2019)

AI curriculum content

Main categories of AI curriculum content

This analysis covers nine topic areas of AI curricula: algorithms and programming; data literacy; contextual problem-solving; the ethics of AI; the societal implications of AI; applications of AI to other domains; understanding and using AI techniques; understanding and using AI technologies; and developing AI.

As outlined in **Table 8**, these nine topic areas are grouped into three categories: AI foundations; ethics and social impact; and understanding, using and developing AI. The survey respondents were asked to provide information on the time and percentage allocation for these topic areas, which are shown in **Table 9**.

Table 8. AI curriculum areas

Category	Topic area	Competency and curriculum considerations
AI foundations	Algorithms and programming	Together with data literacy, algorithms and programming can be viewed as the basis of technical engagement with AI.
	Data literacy	A majority of AI applications run on 'big data'. Managing the data cycle from collection to cleaning, labelling, analysis and reporting forms one of the foundations for technical engagement with using and/or developing AI. An understanding of data and its functions can also help students understand the causes of some of the ethical and logistical challenges with AI and its role in society.
	Contextual problem-solving	AI is often framed as a potential solution to business-related or social challenges. Engaging at this level requires a framework for problem-solving in context, encompassing things like design thinking and project-based learning.
Ethics and social impact	The ethics of AI	Regardless of technical expertise, students in future societies will engage with AI in their personal and professional lives – many do so from a young age already. It will be important for every citizen to understand the ethical challenges of AI; what is meant by 'ethical AI'; concepts such as transparent, auditable, and fair use of AI; and the avenues for redress in case of unethical or illegal use of AI, e.g. that which contains harmful bias or violates privacy rights.
	The social or societal implications of AI	The social impacts of AI range from requiring adjustments to legal frameworks for liability, to inspiring transformations of the workforce. Survey respondents were asked about the extent to which their curricula targeted these issues. Trends such as workforce displacement, changes to legal frameworks, and the creation of new governance mechanisms were given as examples.
	Applications of AI to domains other than ICT	AI has a wide range of applications outside of computer science. The survey asked participants whether and to what extent AI applications in other domains were considered. Art, music, social studies, science and health were given as examples.
Understanding, using and developing AI	Understanding and using AI techniques	This area included (1) the extent to which theoretical understandings of AI processes were developed (e.g. defining or demonstrating patterns, or labelling parts of a machine learning model); and (2) the extent to which students used existing AI algorithms to produce outputs (e.g. training a classifier). Machine learning in general, supervised and unsupervised learning, reinforcement learning, deep learning, and neural networks were given as examples of AI techniques.
	Understanding and using AI technologies	AI technologies are often human-facing applications which may be offered 'as a service'. NLP and computer vision were given as examples. Respondents were asked about the extent to which learners used existing AI technologies to complete tasks or projects, and/or studied the processes of creating these technologies.
	Developing AI technologies	Developing AI technologies deals with the creation of new AI applications that may address a social challenge or provide a new type of service. It is a specialized field requiring knowledge of a range of complex techniques and skills in coding, mathematics (especially statistics), and data science.

Source: UNESCO (2021*b*)

Time allocations for AI curriculum categories

It must be noted that there is a degree of ambiguity as to what could be considered as part of the AI curriculum. Particularly for countries where AI is embedded in ICT curricula, respondents may not include data literacy, or algorithms and programming, as part of the AI component because they see it as being covered within the ICT curriculum. This also affects the responses in terms of the hour allocations, which for some curricula may not include all of the aspects related to AI. Therefore, the responses to this section should be interpreted as AI content in a curriculum or curriculum component according to the knowledge of the respondents.

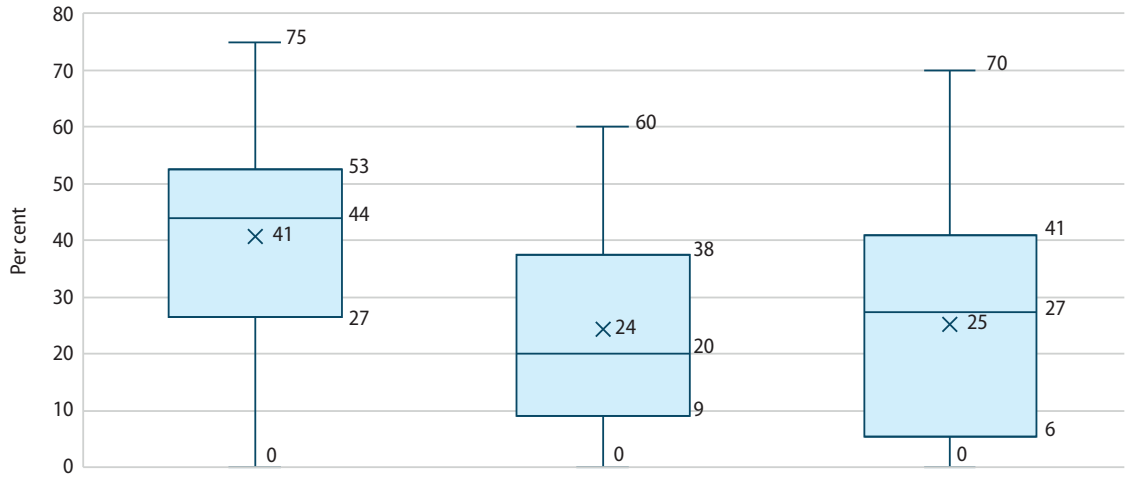
For government-led curricula, official representatives provided their estimations on the percentage of time allocations based on their knowledge of the curriculum and the education system. Some respondents were not able to estimate percentages due to the decentralization of decisions on time allocations or subject integration. Additionally, for some curricula, including those of IBM, Intel, Microsoft and MIT, the percentage allocations were calculated by the researchers from the curriculum content provided and are not estimates from respondents.

Finally, not all curriculum percentages added up to 100 per cent, and not all countries responded to the requests for clarification or submitted additional information on these challenges in follow-up surveys. Therefore, for some curricula, there is a percentage and/or time allocation which is 'unspecified'.

Coverage of AI curriculum categories

'AI foundations', which covers algorithms and programming, data literacy, and contextual problem-solving, formed the basis for most curricula, accounting for a combined average of 41 per cent of curriculum time. The remaining curriculum time is nearly evenly split between ethics and social impact (accounting for an average of 24 per cent of the hours), and understanding, using and developing AI (accounting for an average of 25 per cent). **Figure 7** provides a comparison of these three areas.

Figure 7. Boxplot of focus areas by per cent of curriculum hours (n = 21)[21]



Source: UNESCO (2021*b*)

When the total time commitment in hours rather than percentages is considered, it becomes clearer that by far the largest share is devoted to AI foundations. This area has more than treble the commitment of ethics and social impact and more than twice the commitment of understanding, using and developing AI (see **Table 9**).

Table 9. Curriculum engagement by topic area

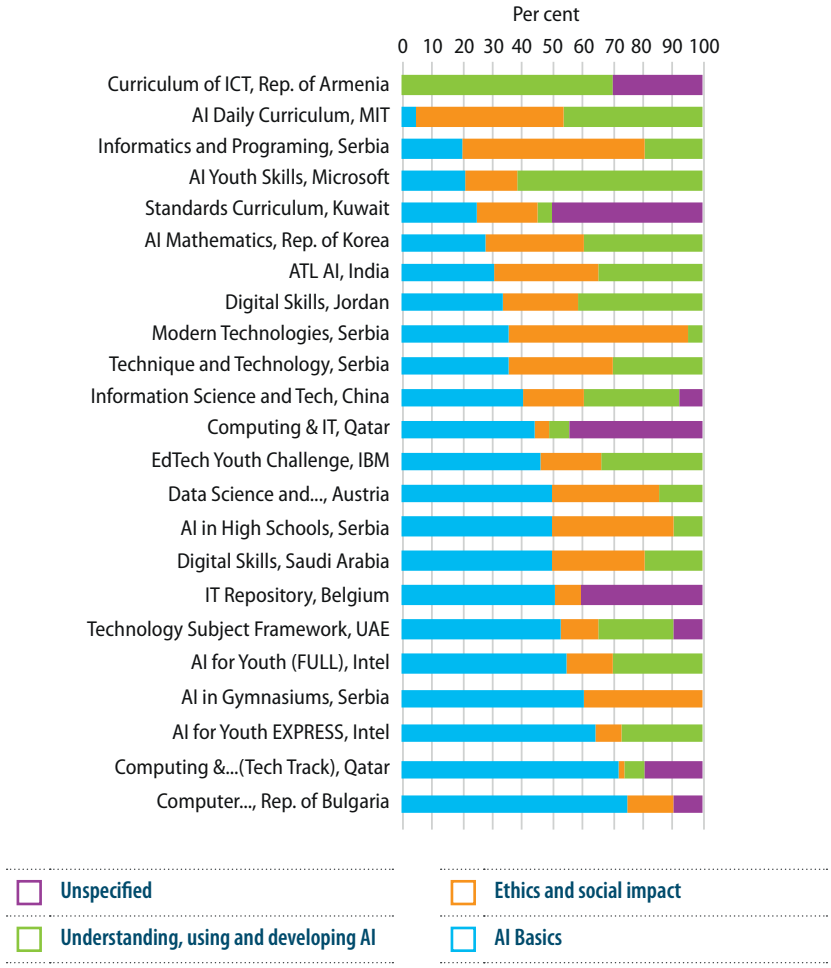
	AI foundations	Ethics and social impact	Understanding, using and developing AI
Number of curricula covering the topic area (n = 21)	20	20	18
Range of hours	0–432	0–185	0–465
Average hour commitment (all)	99.8	29.7	39.0
Average hour commitment (for those with allocations)	104.8	31.2	45.5
Median hour commitment (for those with allocations)	31.3	13.7	11.9

Source: UNESCO (2021*b*)

21 Percentage allocations for one curriculum from the Republic of Korea and the curriculum from the Yukon Territory of Canada were not reported.

As implied by the spread in **Figure 8** and the range in **Table 8**, the curricula have different focus profiles. AI foundations comprised from zero to 75 per cent of allocated curriculum time; ethics and social impact from zero to 60 per cent; and understanding, using and developing AI from zero to 70 per cent.

Figure 8. Allocation of curriculum time by topic area (n = 23)



Source: UNESCO (2021*b*)

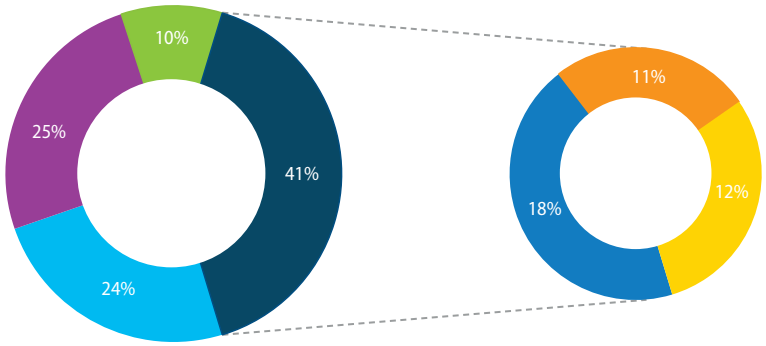
Given the hour and percentage allocations, we can conclude that curricula with a focus on ethics and social impact generally have shorter time commitments than curricula on AI foundations or understanding, using and developing AI. What follows is a closer examination of the sub-topics included in each area.

AI foundations

The AI foundations category includes data literacy, algorithms and programming, and contextual problem-solving. Overall, AI foundations accounted for 41 per cent of the total time allocation, with the largest share of this being allocated to algorithms and programming, followed by data literacy and contextual problem-solving in nearly equal measure.

Only one curriculum had no time for the AI foundations category: the Curriculum of ICT from the Republic of Armenia. It devoted a total of seven hours to engagement with AI as part of the required ICT subject covered in middle and high school. **Figure 9** provides a detailed view of the AI foundations components and their percentage allocations.

Figure 9. Percentage allocations for AI foundations (n = 21)



AI FOUNDATIONS	41%	Algorithms and programming	18%
Ethics and social impact	24%	Data literacy	12%
Understanding, using and developing AI	25%	Contextual problem-solving	11%
Unspecified	10%		

Source: UNESCO (2021*b*)

The topic area of algorithms and programming was covered by 21 out of 23 curricula, the exceptions being Armenia's Curriculum of ICT and the IBM EdTech Youth Challenge curriculum. A further six curricula allocate 10 per cent or less of AI teaching time to this area. On the other end of the spectrum, the Computer Modeling, Information Technology and Informatics curriculum from the Republic of Bulgaria devotes 65 per cent of teaching time to this topic. Overall, curricula were least likely to engage contextual problem-solving. However, curricula that do include contextual problem-solving invest an average of 42.5 hours to it. These curricula are outliers which invest heavily in contextual problem-solving as part of a project-based learning cycle. **Table 10** shows the number of curricula covering each of these topic areas, along with their ranges of hours and average time commitments.

Table 10. Curriculum engagement for the AI foundations category by topic area

	Algorithms and programming	Contextual problem-solving	Data literacy
Number covering the topic area (n = 21)	19	14	17
Range of hours	0 – 269	0 – 198	0 – 78
Average hour commitment (all)	50.0	28.3	21.5
Average hour commitment (for those with allocations)	55.3	42.5	26.5
Median hour commitment (for those with allocations)	10.8	18.6	25.5

Source: UNESCO (2021*b*)

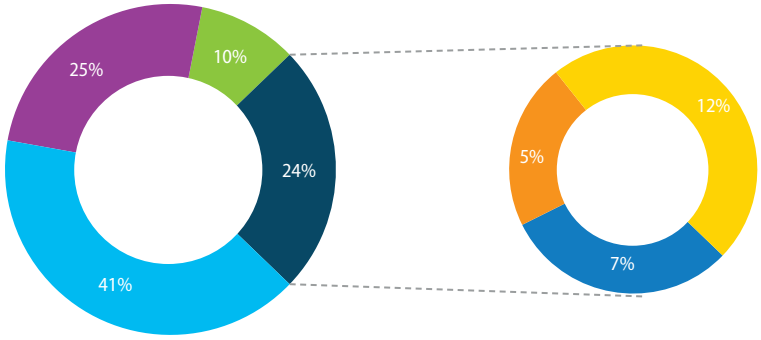
Ethics and social impact

The topics for the category of ethics and social impact include the ethics of AI, the social implications of AI, and applications of AI to other domains, the latter being particularly pertinent to the everyday interactions children and adults will have with AI.

Overall, this category represented 24 per cent of the content on average, but with a wide range of time investments, from zero hours in Armenia's Curriculum of ICT to 185 hours in Kuwait's Standards Curriculum. Percentage wise, Qatar's Computing and Information Technology (High Tech Track) committed less than 5 per cent, while on the other end of the spectrum Serbia's Informatics and Programming curriculum and Jordan's Digital Skills dedicated 60 per cent of their time to this topic area. However, in terms of hours, Qatar's curriculum commits 12 hours to this category, while Serbia's and Jordan's devote only 2 hours.

When the topic areas for this category are considered, it becomes clear that half of the time is for the applications of AI to other domains, with an overall average of 5 per cent spent on social implications, and 7 per cent on ethics (see **Figure 10**). It must be noted that in the two curricula from Qatar, the applications of AI to other domains is covered as part of mathematics, language and science, but a percentage commitment to this topic area was not specified.

Figure 10. Percentage allocations for ethics and social impact (n = 21)



Ethics and social impact	24%	Applications of AI to other domains	12%
AI foundations	41%	Ethics of AI	7%
Understanding, using and developing AI	25%	Social implications of AI	5%
Unspecified	10%		

Source: UNESCO (2021*b*)

Fewer hours were allocated on average to ethics and social impact than to AI foundations, and the percentage allocation of applications of AI to other domains is far higher than ethics or social implications. However, closer analysis shows that this discrepancy is due to a combination of fewer curricula engaging the latter two topics and curricula with higher overall hour commitments incorporating these two areas at very low percentages. As a result, when only curricula that target each topic area are considered, the average hour commitments of all three are nearly equal, and the median hour commitment is lowest for the application of AI to other domains (see **Table 11**).

Table 11. Curriculum engagement for the category ethics and social impact by topic area

	Applications of AI to other domains	Ethics of AI	Social implications of AI
Number covering the topic area (n = 21)	18	17	12
Range of hours	0–92	0–54	0–78
Average hour commitment (all)	11.9	10.8	8.1
Average hour commitment (for those with allocations)	14.1	13.3	14.2
Median hour commitment (for those with allocations)	5.2	6	7.3

Source: UNESCO (2021*b*)

The data provide a few important insights about the ways in which government-endorsed curricula are covering these topic areas.

- First, not all curricula engage the topic areas of this category, and only 12 include social implications.
- Second, the curriculum developers appear to believe the concepts and learning outcomes for all three topics can be achieved with a low number of hours.
- This category tends to be a small part of longer curricula, making up less than 10 per cent of the 144-hour Data Science and Artificial Intelligence from Austria, the two Computing and Information Science curricula from Qatar (both of which are 600 hours), and the 680-hour IT Repository in French-speaking Belgium.
- Finally, this category tends to draw a high percentage commitment from curricula with the smallest hour commitments. For the four curricula with the shortest

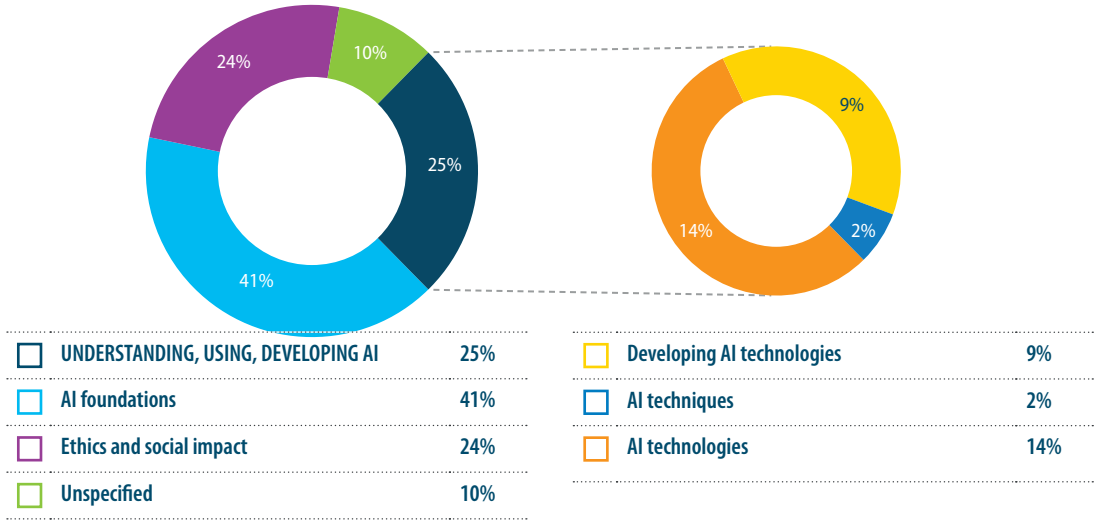
overall allocations, ethics and social impact make up an average of 45 per cent of the curriculum time, with the applications of AI to other domains accounting for 33 per cent of this, the ethics of AI accounting for 10 per cent, and social implications accounting for 1.5 per cent.

Understanding, using and developing AI

This category includes the topics of understanding and using AI techniques (such as machine learning, deep learning, decision trees and neural networks); understanding and using existing AI tools (such as computer vision, classifiers, NLP, and GAN generators); and developing AI technologies, which deals with the programming of AI and the creation of new tools or techniques.

Understanding, using and developing AI was represented in 25 per cent of the curricula. AI techniques accounted for more than half of this category, while developing AI was on average covered the least, with an average allocation of only 2 per cent (see **Figure 11**).

Figure 11. Percentage allocations for understanding, using and developing AI (n = 21)



Source: UNESCO (2021*b*)

Similar to the findings on contextual problem-solving and the social implications of AI, the low commitment to developing AI technologies emerges largely because few curricula engage this aspect at all. Only 6 of them included it, with allocations ranging from 2 to 14 per cent. Of these, only four indicated more than 10 hours of engagement in this area: China's Information Science and Technology curriculum, Intel's AI for Youth Global Development Skills (full version), Microsoft's AI Youth Skills, and Qatar's Computing and Information Technology (High Tech Track). Three of these four curricula require at least 150 hours of study per year. In interviews, some respondents from these countries indicated that they felt the role of primary education was to expose students to AI and its applications in work and everyday life, but that the development of AI was better suited to specialized tertiary study.

Respondents emphasized that the curricula on AI development must be adequately grounded in the relevant subject expertise. The most cited example was mathematics, where alignment is needed between maths principles and expectations around the use of coding and algorithms. Responses to this requirement vary. Portugal is an example of a country which has embedded large parts of its AI learning outcomes in 'computational thinking' within the subject of mathematics, while China has designed its ICT curriculum according to the year-by-year mathematics requirements. In devising a curriculum for high schools that would engage more heavily with AI development, MIT initially targeted science subjects, but found that science teachers are more interested in the applications of AI than its development. MIT are considering maths teachers as perhaps more grounded in the computational theory that underpins AI development.

Table 12 provides the averages, medians and ranges of hours dedicated to the topic areas for understanding, using and developing AI.

Table 12. Curriculum engagement for the category of understanding, using and developing AI, by topic area

	Developing AI technologies	Understanding/using AI techniques	Understanding/using existing AI technologies
Number covering the topic area (n = 21)	6	18	12
Range of hours	0–30	0–128	0–307.5
Average hour commitment (all)	3.3	14.6	21.1
Average hour commitment (for those with allocations)	11.7	17.0	36.9
Median hour commitment (for those with allocations)	11.3	5.5	11.1

Source: UNESCO (2021*b*)

Interestingly, there is a preference for AI techniques over AI technologies. This must be interpreted within the context of the fact that there are AI tools specifically designed to assist learners in unpacking and understanding AI techniques through active or experiential learning, such as Teachable Machine and MachineLearning4Kids. AI tools like these were cited as resources in Austria's Data Science and Artificial Intelligence curriculum, Armenia's Curriculum of ICT, Bulgaria's Computer Modeling, Information Technology and Informatics, the IBM EdTech Youth Challenge curriculum, the two Intel AI for Youth curricula, India's ATL AI modules, the MIT DAILy Curriculum, the Microsoft AI Youth Skills curriculum, Qatar's two Computing and Information Technology curricula, the UAE's Technology Subject Framework, and the Applied Design, Skills and Technologies curriculum from Canada's Yukon Territory.

Example: AI curriculum content in Austria

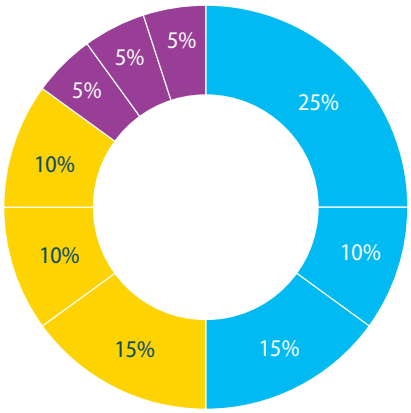
> "Modern education and work processes are hardly conceivable without the use of digital technologies, just like participation in our society.
>
> – Digital Education Curriculum, Austria (Federal Ministry for Digital and Economic Affairs, Austria, 2018)

The Austrian Data Science and Artificial Intelligence curriculum includes digital basics such as using an operating system to store and print files, design presentations, and use spreadsheets and word-processing software. It also covers design and reflection on types and social issues in digital media, and safe digital media use.

Students in high school engage programming languages, algorithms and simulations. They learn the basic principles of data literacy, including collecting data, structuring a spreadsheet, and carrying out analyses and visualizations. They apply criteria to evaluate the credibility and reliability of data sources as well as digital content. Students are expected to know about careers in ICT, including AI, and the social applications of emerging technologies. They create digital media and learn about the cloud and how to connect and network computers. They also gain an understanding of the ethical dilemmas that are associated with the use of such technologies, and become active participants in social discourse on these issues. Finally, students are tasked with using technology to make public statements and understand how this reflects the democratic process.

The curriculum is offered in schools as a required subject for credit and includes 144 learning hours. Fifty per cent of the allocated time, or 72 hours, is spent on AI foundations: 25 per cent on algorithms and programming, 10 per cent on contextual problem-solving and 15 per cent on data literacy. Ethics and social impact takes up 35 per cent of the time, or 50 curriculum hours: 15 per cent on the application of AI to other domains, and 10 per cent each on ethics and the social implications. The remaining 15 per cent, is spent on understanding, using and developing AI, evenly split with 7 hours allocated to each of its sub-topics (understanding and using AI techniques, understanding and using AI technologies, and developing AI). **Figure 12** provides the percentage allocations by topic area for this Austrian curriculum.

Figure 12. Percentage allocations by topic area



Algorithms and programming	25%	Applications of AI to other domains	15%	AI techniques	5%
Contextual problem-solving	10%	Ethics of AI	10%	AI technologies	5%
Data literacy	15%	Social implications of AI	10%	Developing AI	5%

Source: Federal Ministry for Digital and Economic Affairs, Austria, 2018

Learning outcomes of AI curricula

Methodology for analysing learning outcomes

To construct this section, the learning outcomes of the curricula were extracted through an analysis of the frameworks and programmes of study. In line with the aims of this research, the curricula were not analysed comparatively, but examined in aggregate to map out the specifications across grade levels. The results show the types of engagements that were cited as curriculum objectives. It is important to note that this section makes no claim on what should or should not be included or covered in a K–12 AI curriculum, but merely represents what the current practices encompass.

In addition to the learning outcomes presented in this section, some curricula touch on some competences that are required for later work in the advanced study of technology, but which were not directly related to AI. These included gaining familiarity with computers and their operating systems; developing an awareness of the internet as a vehicle for information exchange; using software to work with text, sound, photos and drawings; creating and sharing media through ICT; practicing typing skills; using collaborative software; and understanding computer networking.

Framework for the categorization of learning outcomes

The presentation of this section corresponds to the major aspects of competence-based education. The OECD (2016) defines 'competence' as a combination of knowledge, skills, values and attitudes which is executed in order to address complex demands in a particular context. While it is important not to lose sight of the interrelations between the cognitive, psychomotor and affective domains, for ease of reference this report focuses on the learning outcomes of curricula in three parts: (i) knowledge, (ii) skills, and (iii) values and attitudes.

Knowledge deals with the cognitive demands, both general and domain-specific, deemed necessary to engage in competences. The knowledge outcomes commonly utilize verbs such as 'know', 'understand', 'reflect', and 'compare'. Skills refer to the psychomotor aspects, and outcomes related to skills commonly include verbs such as 'use', 'create', 'build', 'revise', and 'write'. For this classification, 'skills' also include the analysis and revision of technological artefacts and products. Values comprise the guiding principles that determine how one designates priorities when making a decision or taking action, and together with beliefs form the basis for attitudes and attributes and their influence on behaviour (IBE, 2013). Values and attributes can be implicit and unstated, stated explicitly within curricula, or embedded in learning outcomes via adjectives such as 'creative' or 'independent' or adjective-noun compounds such as 'critical thinking'.

The development of values is increasingly emphasized in international forums and literature. The purpose of this text is not to interrogate the viability or rationale of incorporating values into education, but rather to draw out the values and attitudes which are implicitly or explicitly interwoven into AI curricula. It is, however, important to note one key feature of values. Values are not immutable attributes. They can shift according to the context or situation (Haste, 2004, 2018). Therefore, the values presented in this section should be understood within the contexts of the fixed (although diverse) set of countries in this research.

This report presents the implicit and explicit values of the analysed curricula in four categories as presented by the OECD (2019): personal, dealing with how one defines and pursues personal goals; social, dealing with interpersonal relationships; societal, which deals with the shared priorities of cultures or societies and may be enshrined in law; and human, or values which reflect shared priorities that transcend national and cultural borders.

Knowledge and skills outcomes are presented under the categories and topic areas presented in the previous section (entitled 'AI curriculum content'). The categories are: AI foundations, including the topic areas of algorithms and programming, contextual problem-solving, and data literacy; understanding, using and developing AI, including the topic areas of AI techniques, existing AI technologies, and developing new AI technologies; and ethics and social impact, including the topic areas of applications of AI to other domains, the ethics of AI, and the social implications of AI.

Mapping of learning outcomes by AI categories

Knowledge

Table 13. Knowledge outcome mapping

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
AI foundations					
Algorithms	Computational thinking	Understands abstraction	X		
		Understands decomposition	X		
		Explains the roles of decomposition, abstraction, pattern recognition and algorithms in computation		X	
		Discovers commonalities and rules (patterns) in instructions			X
	Algorithm definitions and applications	Understands what algorithms are and do	X	X	X
		Understands that learning algorithms are sets of instructions created by humans to modify an input to create an output		X	
		Identifies examples of types of algorithms (classifiers, generators, regression)		X	
		Recognizes and describes everyday applications of algorithms			X
		Recognizes the importance of algorithms in automated digital processes			X
	Algorithm components and processes	Understands the parts of an algorithm (input, steps to change input, output)		X	X
		Understands the process of training, testing and deploying algorithms		X	
		Compares and contrasts the searching and sorting of algorithms			X
		Analyses the flow of execution of a recursive algorithm			X
		Understands regression algorithms			X
		Compares how advanced data structures are used by algorithms			X
Programming	Programming languages	Develops knowledge of block-based and other programming tools		X	
		Knows different programming languages and production processes		X	X
	Representation and simulations	Understands rule-based reasoning		X	
		Develops an awareness of iterative processes in creating artefacts			X
		Develops knowledge of simulations/models/computational abstractions of real-world physical systems		X	
		Reflects on the limits and possibilities of simulations			X
Contextual problem-solving		Discusses and assesses the power and applicability of various AI approaches to practical problems		X	
Data literacy		Understands data trends	X		
		Understands the principles and processes of data collection and simple analysis	X		
		Understands how to collect, process, analyse, and report using data		X	X
		Understands the types of sources of information		X	X
		Describes the basic structure of a table in a spreadsheet		X	X
		Describes the characteristics of data and information			X
		Assesses the capabilities of big-data management (e.g. warehousing processes)			X
		Discusses the advantages and disadvantages of big-data cloud storage			X
		Compares structured and unstructured data			X
		Explores encoding techniques to represent data efficiently			X
		Develops an awareness of how the transformation and presentation of large datasets through visualization/modelling can be used for decision-making			X

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
Understanding, using and developing AI					
AI techniques	AI definitions and components	Understands 'weak' and 'strong' AI	X		
		Describes basic terms related to AI		X	
		Understands what AI is (and what it is not)		X	X
		Understands the parts of AI (dataset, learning algorithm, prediction)		X	X
		Understands and uses basic and general terms related to AI and machine learning			X
		Describes the basic features of AI			X
		Understands that AI has underlying algorithms			X
		Understands convergence in AI			X
	Data use in AI	Explains how data is used to make predictions		X	X
		Describes the flow of data through a deep learning network for classification problems		X	X
	History of AI	Knows the history of AI and its development over time		X	X
		Understands different approaches to developing AI			X
	Understanding how AI works	Explains types of AI techniques and how they work (supervised, unsupervised, reinforcement, ML/DL)		X	X
		Understands how neural networks work and their parts (feed forward, evaluation of a prediction for accuracy, back propagation)		X	X
		Understands the concepts and challenges of artificial general intelligence		X	X
		Knows how GANs work and identifies their parts			X
		Explains heuristic searches and how they work			X
AI technologies	Computer and human perception	Compares computer and human perception	X		
		Understands computer recognition	X		
		Understands methods of measuring with sensors		X	
		Understands the role of sensors in data collection			X
		Understands the difference between AI and human intelligence			X
	Understanding AI technologies	Explores AI technology and tools (e.g. classifier)	X		
		Understands the processes of creating and using NLP		X	X
		Explores the principles of data for NLP processing			X
		Understands autonomous systems			X
		Understands recommender systems and the technology behind them			X
		Understands the process of creating and using computer vision			X
		Develops an understanding of advanced technologies (IoT, cloud computing)			X
		Compares and contrasts an IoT device operating system with a typical desktop OS			X
AI development	Design thinking	Understands design thinking		X	X
	Product development	Understands the product development cycle			X
Ethics and social impact					
Applications of AI to other domains		Identifies/explains AI use cases and applications in everyday life	X	X	X
		Describes how AI drives many software and physical systems			X
		Understands new advances and applications of AI			X
		Knows important areas of application in the AI and information technology professions			X

Domain	Sub-domain	Learning outcomes	Grade levels engaged		
			Primary school	Middle school	High school
Ethics of AI	Ethical terms, definitions and examples	Understands what ethical terms such as 'bias', 'fairness' and 'representation' mean in relation to AI		X	X
		Reflects on human rights and ethical issues in technology/AI use		X	X
		Describes the limitations of AI			X
		Understands the ethical considerations and dilemmas which may arise from AI			X
	Access	Understands issues of access to technology			X
	Bias	Explains how the biases of the programmers influence the fairness of the AI rules			X
		Understands the effects of information quality in decision-making			X
		Understands algorithmic bias and types/sources of bias		X	X
		Understands methods of mitigating/lessening bias in AI algorithms		X	
		Understands different types of bias (representation, selection, etc.)			X
		Analyses cases where AI has been clearly fair or unfair			X
	Intellectual property	Understands intellectual property rights	X		
		Defends a position on ownership of art generated or enhanced by AI		X	
		Understands/respects basic intellectual property laws		X	
	Privacy and security	Develops an awareness of cybersecurity	X		
		Develops deep knowledge of the concept of digital identity			X
		Understands how digital service providers inform users about how personal information is used			X
		Understands how personally identifiable information can be used and shared			X
	Transparency / explainability	Understands the mechanisms of image and data manipulation			X
		Understands the principle of explainable AI and its tenets			X
	Human agency	Understands that humans control AI and machine learning		X	X
		Understands usability, security, and accessibility of computer systems as key features of their design			X
		Understands how to ethically create and/or use AI			X
Social implications of AI	AI's advantages and disadvantages	Understands how AI can benefit humans	X	X	X
		Reflects on the advantages and disadvantages of new technologies	X	X	X
		Outlines the advantages and disadvantages of AI in different social, educational, and professional contexts			X
	AI in everyday life and work	Considers the role, importance and/or impact of new technologies on society (life, work and education)	X	X	X
		Explores emerging technologies that have the potential to disrupt the way people live, learn and work		X	X
		Develops an awareness of digital citizenship	X		
		Understands how AI is changing jobs (even outside STEM)		X	
		Understands the benefits of and demands for STEM jobs		X	
		Recognizes the interactions between nature, technology and society			X
	Environmental impacts	Understands the positive and negative environmental impacts of technology	X	X	X
		Knows the computational and environmental costs of generating AI		X	
		Understands how computational and environmental costs can be reduced (more efficient models, evaluation of costs and benefits)		X	
		Understands how computational and environmental costs lead to inequity in developing AI		X	
	Fakes and misinformation	Reflects on positive/negative aspects and social consequences of deepfakes		X	
		Reflects on the social implications of GAN technology (e.g. fake homework)		X	
		Knows the six key features of misinformation[22]		X	
		Understands how misinformation spreads		X	
	Gender	Develops an awareness of gendered consequences/opportunities in technology			X

Source: UNESCO (2021*b*)

22 Cited by the MIT DAILy Curriculum as: 'Invokes emotion; polarization; spreading conspiracy theories; deflecting blame; impersonating or fake accounts; and "trolling" people online'

Skills

Table 14. Skills outcome mapping

Topic area	Description of skills	Grade levels engaged		
		Primary school	Middle school	High school
AI foundations				
Algorithms	Recognizes patterns	X		
	Follows clear instructions for action (algorithms) and carries them out		X	X
	Formulates clear instructions for action (algorithms) verbally and in writing		X	X
	Creates an algorithm and the relevant flow chart iteratively		X	X
	Creates a predictive model			X
	Implements complex data structures and fundamental algorithms (e.g. for sorting and searching)			X
	Evaluates the efficiency of an algorithm in terms of time and space			X
	Optimizes computational procedures (to require fewer steps)			X
Programming	Programmatically controls a robot	X		
	Constructs simple code scripts using block-based programming	X		
	Creates a mobile application with a block-based programming language		X	
	Converts algorithms to code using a text-based programming tool		X	
	Codes in one or more programming languages		X	X
	Masters basic programming structures (e.g. branches, loops, procedures)		X	X
	Assesses user interfaces (usability, intuitiveness) and the technical processes behind them			X
	Uses, creates and reflects on coding (e.g. cipher, QR code)			X
	Creates code to manipulate local data files			X
	Creates software to control a robot or another computing device			X
	Uses modular programming methods in a variety of programming languages			X
	Develops an application using object-oriented programming			X
	Develops secure and user-friendly programs taking into consideration accessibility requirements			X
Contextual problem-solving	Creates simple programs or web applications with suitable tools to solve a specific problem or perform a specific task		X	X
	Designs, develops and employs strategies for solving real-life problems through decomposition and pattern identification			X
	Evaluates possible technological solutions and selects a suitable one, also taking into account proprietary and free software			X
Data literacy	Saves, changes and sorts simple databases	X		
	Creates visualizations of numerical and textual data	X		
	Searches for, selects and collects data from a range of sources using appropriate search strategies	X	X	X
	Organizes collected information (e.g. by using data labels and categorizing)	X	X	X
	Manipulates data, makes calculations, and creates simple charts with a spreadsheet	X	X	X
	Uses ICT tools to manage and maintain a relational database		X	X
	Works with relational databases to produce reports		X	X
	Evaluates the quality, authenticity, and accuracy of data		X	X
	Applies criteria to assess the credibility and reliability of data sources			X
	Implements automated data collection processes and manages data storage on a wide range of physical media and cloud platforms			X
	Parses IoT data streams and creates alerts for anomalous conditions such as extreme winds			X
	Transforms unstructured data into structured data			X
	Uses software tools or platforms to organize, calculate, present, and safeguard data			X
	Creates SQL scripts to manage normalized databases			X
	Uses ICT tools to transform data into information to support accurate decision-making			X
	Uses a range of models and charting methods to analyse, predict and communicate data stories			X

Topic area	Description of skills	Grade levels engaged		
		Primary school	Middle school	High school
Understanding, using and developing AI				
AI techniques	Classifies objects by characteristics	X		
	Constructs a decision tree (paper prototype)		X	
	Designs a workflow to train and test an AI algorithm		X	X
	Cleans and prepares textual data for analysis and ML			X
	Designs and tests supervised learning solutions for classification problems			X
	Uses open-source AI application frameworks to build simple intelligent systems			X
	Interprets the performance of a ML model (e.g. using a confusion matrix)			X
	Identifies whether various media products are GAN or not			X
	Creates GANs in different subject areas (music, art, biology)			X
	Creates a story and illustrations using GANs			X
AI technologies	Builds and tests a classifier using a teachable machine or similar AI tool		X	
	Builds a chatbot with support		X	
	Constructs and controls a simple robot that can use AI		X	
	Programs an autonomous robot		X	
	Sets a new goal for an existing AI algorithm		X	
	Uses existing AI technologies to develop new products			X
	Constructs and prepares a dataset for NLP processing			X
	Creates a chatbot with appropriate human/bot interfaces			X
AI development	Works as part of a team	X		
	Uses design thinking methodology to implement a project as part of a team		X	X
	Creates innovative solutions through AI tools			X
	Manages a technology-development project			X
	Verifies the correctness of the technological solutions applied			X
Ethics and social impact				
AI applications	Uses algorithms to produce art, music, etc.	X	X	X
Ethics of AI	Protects personal data and own/others' privacy	X	X	X
	Identifies instances of bias in AI algorithms		X	
	Identifies the stakeholders/beneficiaries of an AI algorithm		X	
	Builds an ethical matrix for an algorithm (stakeholders and their values)		X	
	Researches exposed private data on the internet		X	X
	Manages digital identities and reputations and demonstrates an understanding of digital footprints			X
	Queries messy data in a table, and find bias			X
	Undertakes self-advocacy and redress (e.g. if rights are violated)			X
	Designs an end-to-end ML process that maximizes transparency and ensures fairness			X
	Writes guidance for AI developers to ensure that AI is made ethically			X
Social implications of AI	Properly disposes of technology	X		
	Identifies deepfakes (independently and with AI)		X	
	Recognizes developments that pose a threat to equal opportunities in the use of IT and identifies options for action		X	X
	Compares, analyses and evaluates information and digital content critically (e.g. to recognize manipulation)		X	X
	Avoids health risks and threats to physical and mental well-being related to IT			X
	Helps shape social development by participating in public discourse			X

Source: UNESCO (2021*b*)

Values

Table 15. Values and attitudes outcome mapping

Value / attitude to be developed	Examples of related knowledge and skills outcomes	Grade levels engaged		
		Primary school	Middle school	High school
Personal				
Interest in ICT	Explores existing AI tools	X	X	X
	Creates innovative solutions through AI tools	X	X	X
Persistence / resilience	Solves problems using programming methodology Tests and redesigns artefacts and products	X	X	X
Personal empowerment	Creates a project using design thinking Researches exposed private data on the internet Identifies avenues of redress if personal rights are violated		X	X
Reflection	Reflects on how 'my personal future work' may be impacted by AI Describes the role and importance of AI and its applications Explores emerging technologies that have the potential to disrupt the way people live, learn and work		X	X
Critical thinking and reflection	Designs, develops and employs strategies for solving real-life problems using computational thinking Explains how the programmers' bias influences the fairness of AI rules Compares, analyses and critically evaluates information and digital content (e.g. to recognize manipulation)			X
Entrepreneurship	Uses design thinking methodology to produce a prototype Develops awareness of entrepreneurship principles/processes to implement innovative ideas			X
Social				
Collaboration / teamwork	Works as part of a team or group Implements a project as part of a team Collaborates online as a member of a team	X	X	X
Communication	Creates a story and illustrations using GANs Writes guidance for AI developers to ensure that AI is made ethically			X
Societal				
Respect for others	Engages respectfully with others Protects personal data and own/others' privacy	X	X	X
Personal responsibility	Disposes of technology properly Understands that humans control AI and ML	X	X	X
Integrity	Understands methods of mitigating/lessening bias in AI algorithms Designs an end-to-end ML process that maximizes transparency and ensures fairness		X	X
Tolerance	Shows tolerance for different ideas/positions		X	X
Human				
Respect for the environment / sustainable mindset	Understands the environmental impact of technology Recognizes the interactions between nature, technology and society Understands how computational and environmental costs can be reduced	X	X	X
Commitment to equity	Reflects on access to AI Understands how computational and environmental costs lead to inequity in developing AI		X	

Source: UNESCO (2021*b*)

Example: Progression of AI learning outcomes in the Republic of Korea[23]

The Republic of Korea's elementary and secondary AI curriculum standards were published in 2020, and a national curriculum for AI is under development. Local governments and schools can flexibly modify curricula to fit within the given hours and frameworks of the standards. In 2020, an AI school curriculum for high schools was implemented. As this curriculum is offered at the discretion of the principal, it has the potential to reach 2,367 high schools. The country has 500 'AI education leader' schools which are specifically focused on cultivating talent in the technology sector.

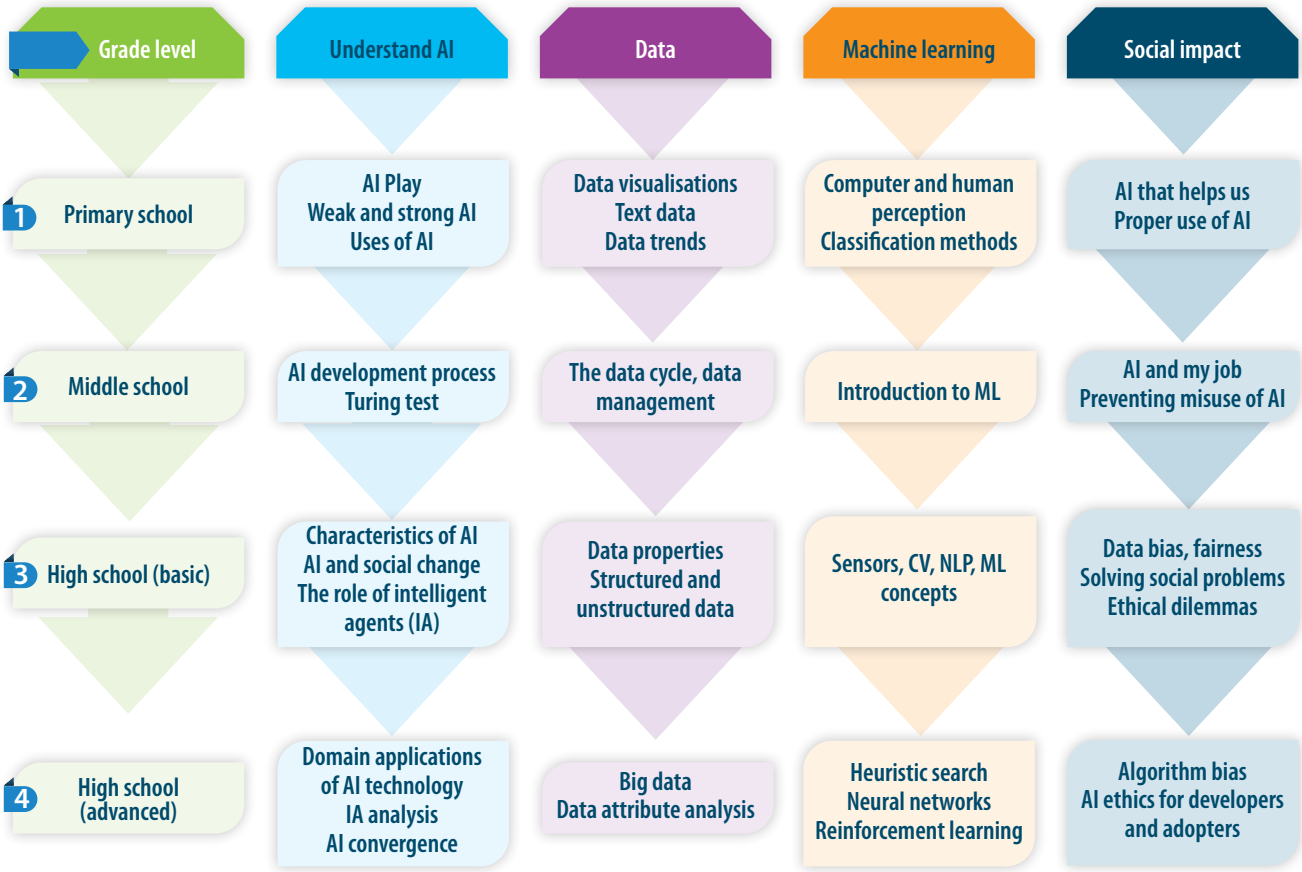
The curriculum builds on compulsory coding modules in elementary, middle and high schools, but requires no prior knowledge of AI.

The content standards for the Korean AI curriculum cover three domains:

1. Understanding AI, with sub-domains 'AI and society' and 'Intelligent agents'
2. Principles of AI and its application, with sub-domains 'Data', 'Recognition', 'Classification, exploration and reasoning', and 'Machine learning and deep learning'
3. The social impact of AI, with sub-domains 'AI influence' and 'AI ethics'.

Figure 13 outlines the curriculum progression for some of the learning goals in four key areas: understanding AI; data; machine learning (including classification); and social impact.

Figure 13. Curriculum Standards, Republic of Korea



Source: Interview and written submissions from Professor Ki-Sang Song

23 Information in this section is derived from verbal and written responses to interview questions provided by the respondents.

Curriculum implementation

Teacher training and support

Upskilling existing teaching staff

Most training strategies for government-endorsed curricula pursued the upskilling of existing staff. Some countries, e.g. China and Portugal, indicated that the preparation strategy leverages national training initiatives or projects for the teachers of subjects in which AI is embedded. In other areas such as Belgium, teacher-training programmes are decentralized and undertaken by education networks, and therefore may vary between regions, languages and types of schools (e.g. public or private).

Non-governmental actors tend to undertake other methods of teacher training. For the MIT DAILy Curriculum, teachers from three districts in the USA participated in training which included both general sessions and 30 hours of implementation practice at summer camps hosted by NGO partners. Industry partners engage in the delivery of training courses remotely or through blended-learning methodologies. For instance, a partnership between IBM and Macquarie University's School of Education created the 16-hour Artificial Intelligence (AI) Education for Teachers course hosted on Coursera. The course covers topics such as the history of AI, comparing AI and human intelligence, and ethical considerations in developing and using AI. Some providers offer certification. Intel does this for coaches and lead coaches, the latter of which are often positioned as trainers of trainers.

Integrating AI into initial teacher preparation

In Austria, the primary strategy for teacher training was to embed AI topics into initial teacher education at higher education institutions, which were expected to cover not only general AI topics but also the use of AI to support pedagogical processes and teaching and learning.

Supporting in-service teachers

In addition to the creation of standards, national and regional governments support the implementation of AI curricula through the development of resources. For example, in Serbia the implementation is bolstered by online tools including videos, presentations, and interactive tasks that were developed for the various AI curricula offered in the country. National or regional initiatives also produce resources such as textbooks and assessment guidelines to support the AI curriculum prior to implementation.

The MIT DAILy Curriculum provides materials to teachers including slide decks, talking points and full lesson plans that they can use or adapt. Industry partners such as IBM, Intel and Microsoft supply them with learning pathways and content through global, open online resources. These partners have also created context-specific teacher resources for implementing countries, including manuals, facilitator handbooks and AI textbooks.

Learning tools and environments

In addition to leveraging existing infrastructure initiatives to deliver hardware and internet connections, curricula engage a range of resources to support implementation in schools. In cases such as Belgium and China, the decision on tools and environments was not centralized and therefore specifics could not be given. On the other side of the continuum, in the case of Serbia, online tools including interactive tasks are being generated to strengthen the curriculum. Other curricula leverage existing environments and tools, engaging a range of free products. The representatives from Austria and the UAE made the following comments respectively:

> "We use Jupyter Notebook/Lab, Python, PyCharm, and Python libraries for AI (Scikit-learn, Keras, Tensorflow). We focus on natural language processing, image analysis, and big data analysis.

> We use different resources and platforms based on the students' grade levels. Online tools like Code.org, Microsoft and AI, MachineLearning4Kids, and IBM and AI Robotic Kits such as Magkinder Labeeb, Fateen, Maker, Maker with Robotics Car, and Raspberry-Pi are used in different AI projects. The tools are used to train different models, understand machine learning algorithms, and complete online tasks related to AI. Students at higher grades will be introduced to Python so that they can implement different ML algorithms.

The AI curricula did not all engage coding or programming, but many included these elements, often using introductory programming languages and tools such as PictoBlocks or Scratch. The introduction of the programming language Python was common, particularly in curricula targeting senior secondary schools, though some curricula also included HTML and Java.

A wide range of AI technologies such as Alexa, GAN image generators, Google Assistant, Pix2Pix, PoseNet, robotics kits, and simulation software were included in curricula, allowing students to explore the myriad ways in which AI can be used in different subject areas. Students who engaged in the creation of AI were most likely to do so through free software such as MachineLearning4Kids and Teachable Machine. These tools allow children to explore and build ML models to carry out tasks such as classifying objects. As students advance into higher grades, some curricula further engage ML libraries and tools like Scikit-learn.

Off-line environments were also leveraged by the MIT DAILy Curriculum. In addition to encouraging the exploration of online tools and resources, it included off-line games, e.g. a group activity where students act out the information flows in a GAN, and another in which they build a paper-based decision tree classification system for different types of pasta. In the case of China's Information Science and Technology, the curriculum is required to serve a range of schools and regions at varying levels of ICT access and integration, and therefore provides a series of learning outcomes without recommending specific technologies or tools for delivery, in order to accommodate both online and off-line options.

The following tools and instruments were suggested in the curricula based on the areas of AI on which the curricula focus:

- **Hardware and robotics**

The hardware needed for AI curricula includes computers, tablets, laptops, and internet/web access. Not all AI curricula include content on robots or robotics. When the learning on robots is required, curricula need to leverage kits such as Lego Mindstorm EV3,[24] Magkinder Labeeb,[25] and/or Maker Robotics.[26]

Devices like Raspberry Pi[27] are used by some curricula that require students to create programs and test them using low-cost devices.

- **Software**

The Ubuntu[28] open-source operating systems were used by some curricula as less expensive alternatives to other operating systems.

- **Programming languages**

Curricula often leveraged free programming languages such as:

  - HTML[29]
  - Javascript[30]
  - Python[31]
  - Micropython[32]
  - NumPy[33]
  - R[34]
  - Scratch[35]

- **Tools for learning AI techniques**

A number of tools have been developed to facilitate understanding and allow the exploration of complex concepts and AI techniques, including the following which were specifically mentioned in the AI curricula in this study:

  - MachineLearningForKids[36]
  - Teachable Machine[37]
  - TensorFlow[38]
  - Keras[39]
  - OpenVINO[40]
  - Scikit-learn[41]

24 See https://www.lego.com/en-us/product/lego-mindstorms-ev3-31313
25 See https://shop.ibtikar.io/en/magkinder-labeeb-151-pcs-set
26 See http://site.makerrobotics.com.br
27 See https://www.raspberrypi.org or https://www.raspberrypi.com
28 See https://ubuntu.com/download
29 See https://www.w3schools.com/html
30 See https://www.w3schools.com/js
31 See https://www.python.org/psf
32 See https://micropython.org
33 See https://numpy.org
34 See https://www.r-project.org/about.html
35 See https://scratch.mit.edu
36 See https://machinelearningforkids.co.uk
37 See https://teachablemachine.withgoogle.com
38 See https://www.tensorflow.org
39 See https://keras.io
40 See https://docs.openvino.ai/
41 See https://scikit-learn.org/stable

- **Databases**

When the development of data-dependent AI tools is required in the curriculum, databases are needed so that students can test the programs and optimize the algorithms, for instance:

  - Coco, a large-scale object detection, segmentation, and captioning dataset[42]
  - ImageNet, an image database with over 14 million images[43]

- **Tools and resources for learning AI technologies**

When students are asked to apply the pedagogical methodology to technologies that follow the Use-Modify-Create model, examples of tools based on different categories of AI are needed. It is important to highlight the 'agnostic approach' to AI technologies, and explain to students that AI technology is not limited to a particular brand or tool.

  - GAN image generators, such as GANpaint[44]
  - NLP tools such as Google Assistant[45] and IBM Watson[46]

Both academic bodies and commercial companies have been offering online programming courses or spaces for learning AI. This report suggests that to prevent the AI curriculum from linking to particular brands or AI tools, the national or local curriculum authorities should curate and validate openly licensed or non-commercial learning tools, and create public online platforms or spaces to support the teaching and learning of AI.

Suggested pedagogies

Respondents to the survey were asked about the pedagogical recommendations included in the curriculum or its delivery. The options that they had to choose from are outlined in **Table 16**. Multiple selections were possible, and they also had the opportunity to provide free responses.

Table 16. Suggested pedagogical approaches and specifications

Pedagogical approach	Definition
Lecture or instruction	Refers to didactic, teacher-led classes. Information is delivered verbally, in print or through a combination of media, by a teacher, facilitator or expert.
Group work	Teaching and learning which requires students to collaborate to complete one or more tasks. Group work is intended to allow students to approach more complex tasks and practise skills such as teamwork.
Project-based learning	Learners leverage their skills and competencies to identify and/or respond to a real-world challenge over an extended period of time, facilitated by a teacher. Project-based learning is characterized by student autonomy, goal-setting, collaboration, and investigation of real-world contexts (Kokotsaki et al., 2016).
Activity-based learning	Learners progress at their own pace through activities facilitated by a teacher. Activity-based learning usually takes place in classrooms and is designed to foster independence, exploration and experimentation. It is often linked to presentations of work. Key features of activity-based learning are the active involvement of students and collaboration in the classroom (Anwar, 2019).

Source: UNESCO (2021*b*)

The results show that almost all of the curricula relied on lecture or instruction (89 per cent), with a strong dependence on group work and project-based learning as well. Project-based learning was a particularly prominent feature of many curricula, both national and industry. For example, as noted by the representative from Portugal, its national curriculum uses project-based learning through an interdisciplinary approach:

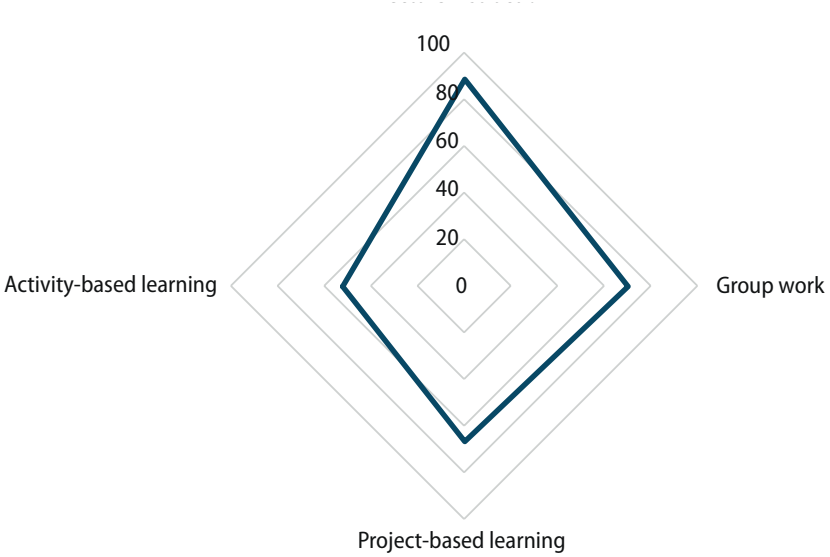
> "Our curriculum says we must use student-centered approaches to learning such a project-based learning. This is meant to be the main pedagogical methodology teachers can use. There is also a need to promote interdisciplinary approaches. Knowledge of one subject must be linked to the knowledge of others.

The types of projects engaged, however, as well as their time commitments, varied between curricula and approaches. Projects could be defined as time-limited activities such as using AI software to perform a translation task, using AI to generate art, or building or manipulating robots through robotics kits. For curricula such as the IBM EdTech Youth Challenge, Intel AI for Youth, Qatar's two Computing and Information Technology curricula, and Microsoft AI Youth Skills, this

42 See http://cocodataset.org/#explore
43 See https://image-net.org
44 See http://gandissect.res.ibm.com/ganpaint.html
45 See https://assistant.google.com
46 See https://www.ibm.com/academic/home

kind of work forms a core part of the engagements, with students undertaking the creation of an AI project through a guided cycle of design thinking. Activity-based learning, on the other hand, was suggested for 14 curricula (52 per cent) and therefore was less emphasized (see **Figure 14**).

Figure 14. Average pedagogical engagement profile (n = 27)



Source: UNESCO (2021*b*)

Additionally, blended and/or remote learning were suggested by all but three curricula (89 per cent), suggesting a heavy reliance on remote expertise for curriculum delivery. Assessment for learning, competency-based education, constructivism, constructionism, experiential learning and student-centered pedagogies were also endorsed or suggested as approaches.

Interestingly, most curricula allowing for remote learning were developed by the public sector or with government oversight. Only two curricula which use remote learning were generated by the private sector: the IBM EdTech Youth Challenge and Saudi Arabia's Digital Skills.

On a final note, the curricula included in the survey responses cover a wide range of AI applications, ethical issues, tools and techniques without depending heavily on mathematics or programming knowledge, and sometimes without relying explicitly on technology at all.

Example: Implementation of the Information Science and Technology Curriculum for Senior High Schools, China

The Ministry of Education of the People's Republic of China published the IT Curriculum for Senior High Schools in 2017. The curriculum is nationally mandated for implementation in 225,000 schools, and reaches over 180 million students. It is divided into 10 modules: 2 compulsory modules, 6 selective modules offered for credit, and 2 selective modules offered without credit. In total, the curriculum requires 54 hours of compulsory modules and 72 of selective modules, for a total of 126 hours. Aspects of AI are included in the compulsory modules, which are 'data and computing' and 'information systems and society'; the compulsorily selective modules, which means all students must choose one of these modules, include 'basics of artificial intelligence' and 'data management and analysis'; and the selective module 'algorithm preliminaries'.

The curriculum aims to guide students to understand what AI is, how it works, and the social issues surrounding its use. While the curriculum is nationally mandated, Provinces modify its implementation based on their population demographics, available resources and educational needs. China's representative explained this as follows:

> "We cannot do the same thing everywhere throughout China. There are different needs in different areas. In advanced cities, for example, they are familiar with the equipment, smartphones and many other things. Our challenge is to guide them to be ethical, respect others and do the right things for society. In other areas, students are less familiar with applications, so the challenge is to guide them to become familiar with devices and applications.

Before being released, the curriculum was reviewed by experts and piloted with students of different grade levels to determine the students' attitudes toward the curriculum content. The curriculum was then revised based on these reviews before being published.

China has undertaken a range of preparation including carrying out research, analysing needs, developing resources, training teachers, installing infrastructure, providing schools with necessary equipment and materials, and improving capacity by hiring additional staff and engaging the third sector and private companies as part-time trainers in schools. The curriculum utilizes a wide range of pedagogies including direct instruction, blended and remote learning, group work, project-based learning and activity-based learning.

To support the implementation, teachers of all subjects are trained through the National-Level Teacher Training Programme. Part of the programme is focused on Information Science and Technology, and includes AI. The National Ministry of Education has two sessions per year during the school holidays, and all teachers are required to join the programme once every three years. There is a concerted effort to ensure that students are familiar with a range of equipment and applications, so both schools and teachers control the types of technology utilized in the classroom. During the training, teachers are exposed to multiple brands of devices and different types of platforms and technologies, and the types of technologies to be used are not explicitly stated in the curriculum.

Key findings and recommendations

The nine key findings and thirteen recommendations presented in this section relate to four main stages of curriculum provision – development and endorsement, integration and management, content and learning outcomes, and implementation – and are categorized here accordingly.

Curriculum development and endorsement

Key finding 1 — Only a limited number of government-endorsed AI curricula have been developed and implemented

To date there are 14 AI curricula which have been developed and implemented by 11 governments. While countries are developing mandates for the inclusion of AI in curricula through policy documents, to date this has not translated into widespread integration of AI into K–12 curricula.

Recommendation 1.1: Further research is needed to determine the extent to which K–12 curriculum reform is mandated in national AI policy or strategy documents, and the extent to which these mandates have been actioned to develop a deeper understanding of the political mechanisms used and the enablers or inhibitors of AI curriculum development and implementation.

Key finding 2 — A strong governmental commitment and validation mechanism is necessary to manage competing interests in curriculum development

There is a wide range of stakeholders in the AI sector, and many of these are active in curriculum development or delivery. AI curriculum development teams included government officials, industry experts, academics, and in some cases, teachers. Without strong coordination and balanced input, conflicting goals may manifest within curricula. Conversely, strong coordination and validation mechanisms can unify the efforts of a range of public- and third-sector partners towards national goals for AI education.

Recommendation 2.1: There is a need for a balanced, multidisciplinary and collaborative approach to the production of AI curricula, undertaken with the overt management of government. Regardless of development status, each country has access to a range of industry, subject-specialist and education-practitioner expertise both within and across national borders, and must consider how this expertise can be best validated, de-commercialized, and curated for the good of students.

Recommendation 2.2: Include teachers in the development with the aim of ensuring that the curriculum is actionable in practice. Teachers can provide practical advice on the knowledge and competencies with which students enter different grade levels, the logistical challenges of integrating technology in different contexts, and the most appropriate methods to engage students. Teachers are also experts in explaining complex concepts to students, and can provide valuable inputs to not only curricula but also support and training materials.

Key finding 3 — An evidence base on the quality and effectiveness of AI curricula is needed.

Published studies on the evaluation of AI curricula remain scarce, and none have been found on the effects of such curricula on the development of AI competencies for students and the building of human resource capacity in AI areas. While some evaluations or pilots of AI curricula did include external feedback from teachers and learners, others relied only on reviews of the curriculum by experts.

Recommendation 3.1: Pilot studies should be carried out and must seek feedback from teachers and students as well as academic and/or industry experts. The implementation of AI curricula and their impact on students should be rigorously evaluated to inform the evidence base.

Curriculum integration and management



Key finding 4 — Resource development and teacher training are essential for curriculum integration

Nearly 90 per cent of curricula were supported by resource development and/or teacher training. However, just over half involved a needs analysis to inform resources or training programmes.

Recommendation 4.1: Engage in evidence-based resource development and teacher training by first gathering information on items such as the existing human capacity within the sector, and the training and support needed in order to integrate and implement an AI curriculum. Include teachers in resource development, and pilot-test the resources before they are released to teachers and students. Make adequate provision for AI concepts and pedagogy to be introduced to in-service teachers and integrated into initial teacher training at higher education institutions. Leverage AI events as opportunities for teacher training.



Key finding 5 — Government-endorsed AI curricula tend to be elective or integrated into existing subjects in schools

Most countries choose to implement AI within an existing subject or subjects, or as an elective or interdisciplinary subject. In all of these cases, it is necessary to determine what will be omitted from or condensed in the existing curricula to create space for substantial engagement with AI. Curriculum developers must also look at whether AI is to be a sub-topic with only a few hours of allocation, or a 'special topic' studied during out-of-school hours, e.g. on a personal interest basis.

Recommendation 5.1: Develop integration maps for a range of existing subjects or themes at different grade levels, which can support the implementation of AI learning outcomes across different topic areas without consuming large proportions of the teaching time of any one subject.

Recommendation 5.2: Consider multiple-modality AI curricula that include out-of-school components such as extracurricular opportunities for mentorship and participation in competitions.

Curriculum content and learning outcomes



Key finding 6 — The goals and learning outcomes of AI curricula should be focused on the main values and skills needed for work and life in the AI era

There is general consensus that AI curricula are important to ensure students have the necessary skills for work and life in the AI era. However, the development of these curricula has been undertaken with a continuum of goals and focus areas ranging from exposure to AI to expertise in building AI. The curricula produced to date demonstrate various understandings of the progression of task complexity and the types of learning outcomes that can or should be considered for students at different grade levels. The goals set for the AI curriculum affected the time commitment, curriculum content and embedding mechanisms of the curricula. The time allocated for understanding AI techniques, learning domain-specific AI technologies, and developing AI is limited and insufficient for fostering the creativity and skills that are needed to create innovative AI tools. Furthermore, without sufficient knowledge of AI techniques and tools, the stand-alone discussion on ethics is not enough to direct students towards an in-depth understanding and ability to apply the principles across the AI lifecycle.

Recommendation 6.1: AI curricula should explicitly align to international and national development goals and strategies. Special consideration should be given to developing skills for work and life in the AI era that can be further defined within particular contexts, providing more opportunities for generating innovative AI tools, and embedding ethics into the contexts of using AI to solve real-life problems.

Recommendation 6.2: Develop, adopt or adapt a coherent sequence of age-appropriate learning activities and outcomes in consultation with curriculum experts, computer scientists and education practitioners, taking into account the end goals of the curriculum, the motivations for its development, and national policy mandates. Interdependencies between different subject areas should be considered.

Key finding 7 — AI learning outcomes can be engaged through both off-line and online activities

The curricula included in this mapping exercise demonstrate that technological access is not a prerequisite for understanding AI and its impact within society, though it is often a requirement for those seeking to cover practical applications, data literacy components, and AI development. There are a range of free resources and AI learning tools and technologies available to teachers and students.

Recommendation 7.1: In low-resource contexts, curricula can focus on areas such as understanding AI, recognizing AI applications in everyday life, reflecting on social impacts, and engaging design thinking through paper prototypes or product redesign exercises.

Curriculum implementation

Key finding 8 — Project-based learning is commonly used as an appropriate pedagogical methodology for AI curricula

A third of the curricula in this study included project-based learning as a pedagogical strategy. The perceived benefits of this type of learning were linked to practical skills development and opportunities for problem-solving.

Recommendation 8.1: AI curriculum developers should consider leveraging innovative pedagogies to create interdisciplinary opportunities to solve real-life challenges faced by students and their communities, as a way to build skills in critical thinking, entrepreneurship, communication and teamwork.

Key finding 9 — AI curricula should not be linked to specific technologies or brands

While adequate learning environments need to be developed for the implementation of curricula, AI education should not be limited to particular brands or products. Students need to acquire basic knowledge, transferable skills, and value orientation on applying AI in different domains and contexts. Due to the pace of change and the development of new technologies and brands, curricula which are product-dependent may quickly lose relevance and students' brand-bound knowledge may not be transferred when they face new contexts or real-life problems.

Recommendation 9.1: Curriculum development should focus on learning outcomes and the application of AI principles and processes rather than the ability to use specific platforms, devices or products. Where possible, curricula should engage a wide range of different technologies.

Recommendation 9.2: Wherever necessary, invest in basic enabling infrastructure to engage a range of AI technologies and learning tools. Ensure that teacher training and other school support mechanisms such as quality assurance or performance reviews are adequately structured to guarantee that this infrastructure can be used for designated learning outcomes.

Concluding comment

The introduction of AI into life and work has already fundamentally changed the way people interact within their societies in both developed and developing nations. It is raising significant questions, e.g. about the expression and protection of human rights, legal liability in AI-related injury, and the philosophical orientation of AI development and use. AI will continue to change the nature of life and work, and therefore a basic understanding of it is now a critical component in the concept of an 'educated citizen', whether or not they will become AI specialists.

Given the importance of AI competencies, and the trajectory of the field of AI and its integration into other domains, it is perhaps surprising that so few countries have sought to formally integrate training in this area into K–12 education. Governments who have invested in this area have done so based on a recognition that AI skills are essential to both the current and future economy of their country and also to the full participation of citizens in social life. An understanding of what AI is, how it works and what it can do empowers students with the ability to better understand their world, advocate for their own and others' rights, and leverage technology and data for the public good.

Governments are called on to ensure that these opportunities are given to all of their citizens through the creation of AI curricula with well-sequenced learning outcomes, aligned to national policy goals and international standards of human rights and ethics. They are further encouraged to attach sufficient attention to building students' creativity in AI and understanding of ethics through deep engagement with the algorithms and data behind the AI tools. Governments should also apply the humanistic approach to the development and implementation of AI curricula to ensure the protection of people's fundamental rights, including data privacy, and the promotion of inclusion, equity, and gender equality. It is also critical to ensure the adequate provision of non-propriety resources and needs-based teacher training.

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Appendix

Survey sent to representatives of Member States

UNESCO mapping of government-approved AI curricula

The purpose of this survey is to gather some high-level information on government-approved **Artificial Intelligence (AI) curricula for K–12 or equivalent grade level**. This could be a discrete curriculum (e.g. for a core subject called AI or an elective), part of a curriculum (e.g. AI units or concepts within an ICT or other subject curriculum), an extracurricular subject, or distributed across multiple subjects. The information will be used as part of a mapping study of UNESCO to identify countries in which AI curricula are being developed and implemented, the grades these curricula cover, the positioning of these curricula as independent or within other subjects, and what is covered by these curricula.

Multiple responses to this survey are possible. If multiple AI curricula are developed or implemented by different developers in your context, or there are differences in the development, endorsement, evaluation or etc. of different grade levels you would like to draw out clearly, please respond separately for each case.

Your contribution is highly appreciated and will help enrich the global knowledge base on AI in education.

Your participation in this survey is taken as consent for the survey and also for the information gathered to be used in the mapping study and any subsequent publications of UNESCO.

General Information

1. What country, regional or international inter-governmental body(ies) are you representing in your responses to this survey? (free response, short answer)
2. Are you aware of the development or implementation of an AI curriculum for students in any grades K–12 in your country/context? [NB: The curriculum may be discrete (only about AI), embedded in another subject (such as ICT/IT subject), or cross-curricular (integrated across many subjects). The implementer of the curriculum may be the national government, private providers or NGOs.]
   - ○ No
   - ○ Yes, an AI curriculum (including one AI curriculum or multiple AI curricula) is developed and endorsed

If your country has government-approved AI curricula and if you are nominated as the focal point for the mapping study of UNESCO on AI curricula, UNESCO may follow up with you if we have additional questions.

3. Please provide your name
4. Please provide your email address
5. Please provide any alternative contact details

AI curriculum 1

[If multiple AI curricula are being developed and endorsed, please provide the information for each one separately by indicating the number of additional curricula at the end of this page and moving to the next page, or get in touch with UNESCO to map the AI curricula.]

6. What is the title of the AI curriculum? (free response)
7. Who is the developer of this curriculum? (free response, short answer)
8. Is the developer:
   - ○ Public sector (e.g. government)

- ○ Private sector (e.g. corporate/industry)
- ○ Third sector (e.g. NGO, civil society organization, public benefit organization, etc.)
- ○ Other (fill in)

9. How is the curriculum endorsed? If different grade levels of the curriculum are endorsed in different ways, please explain under 'other' (tick all that apply)

- ○ The national government has mandated or endorsed the use of this curriculum in schools.
- ○ Local government (e.g. districts or provinces) has mandated or endorsed the use of this curriculum in schools.
- ○ A school or schools have mandated or endorsed the use of this curriculum
- ○ The curriculum provides an industry certification.
- ○ None of the above
- ○ Other (free response)

10. How is the curriculum positioned in the governmental curriculum framework for schools? (tick all that apply)

- ○ In schools as a required subject for credit
- ○ In schools as an elective or optional subject for credit
- ○ In schools as part of the required ICT/IT subject for credit
- ○ In schools as part of the elective or optional ICT/IT subject for credit
- ○ As an interdisciplinary or cross-curricular subject in schools
- ○ As an extracurricular activity in schools
- ○ As an out-of-school activity (e.g. clubs, hackathons, at home)
- ○ Other (free response)

11. How many schools are **currently being reached** by this curriculum? If the curriculum is still in development, please enter a zero. (response restricted to numbers 0 or greater)

12. How many students are reached by this curriculum? If you do not know, please leave this question blank.

- ○ Male
- ○ Female
- ○ Overall (in case male/female is unknown)

13. What grades are covered by this curriculum? (select all that apply)

- ○ Early Primary: K– Grade 2
- ○ Late Primary: Grade 3 to the end of primary school
- ○ Middle or junior school
- ○ Senior or high school
- ○ Other (explain, free response)

14. What is the total number of learning hours assigned to the curriculum? If more than one option is available (if for example there is an optional extension), please provide all times with a brief label of what it describes. (free response)

- ○ Early Primary: K– Grade 2
- ○ Late Primary: Grade 3 to the end of primary school
- ○ Middle or junior school
- ○ Senior or high school

15. If you consider the AI curriculum, what percent of total teaching time would you estimate is allocated to each of the following (if no time is committed to the item, please leave blank):

- ○ Algorithms and programming
- ○ Applications of AI to domains *other* than ICT (e.g. Art, Music, Social Studies, Science, Health, etc.)

- ○ Contextual problem-solving
- ○ Data literacy (e.g. statistics, data collection, pre-processing, data modelling, analysis, interpretation, visualisation)
- ○ Ethics of AI / Ethical AI (e.g. bias, privacy, etc.)
- ○ The social or societal implications of AI (e.g. trends such as workforce displacement, changes to legal frameworks, the creation of governance mechanisms, etc.)
- ○ Understanding and using AI techniques (e.g. machine learning in general, unsupervised/supervised/reinforcement/deep learning, neural networks, etc.)
- ○ Understanding and using AI technologies (e.g. Natural Language Processing, Computer Vision, etc.) (if yes, please specify the AI technologies)
- ○ Developing AI technologies (e.g. Natural Language Processing, Computer Vision, etc.) (if yes, please specify the AI technologies)

16. What learning tools and environments are suggested by the curriculum? (free response)

17. What teacher preparation or mobilisation is taking/has taken place in order to effectively implement this curriculum? (Tick all that apply)

- ○ Research or a needs analysis related to the implementation of the curriculum
- ○ Development of resources for teachers (textbooks, lesson plans, etc.)
- ○ Teacher training on the curriculum and resources
- ○ Hiring of additional staff/capacity for schools to implement the curriculum
- ○ Engagement of the private or third sector for part-time trainers in schools
- ○ Infrastructure upgrades at schools o
- ○ Procurement of additional resources for schools/classrooms
- ○ Other (free response)

18. What suggested teaching methodologies or pedagogical approaches are emphasized in the curriculum and/or any associated training and resources? (tick all that apply)

- ○ Lecture or instruction
- ○ Blended learning (e.g. learning which takes place partly face-to-face, and partly remotely)
- ○ Remote learning
- ○ Group work
- ○ Project-based learning (e.g. learners leverage their skills and competencies to identify and/or respond to a real-world challenge over an extended period of time)
- ○ Activity-based learning (e.g. learners progress through activities facilitated by a teacher at their own pace)

19. Has the AI curriculum been evaluated?

- ○ No
- ○ Yes, please explain how the curriculum was evaluated

20. Has the AI curriculum been revised based on evaluation?

- ○ No
- ○ Yes, please explain how the curriculum was revised

21. Is the curriculum documentation, even in draft form, available for review by the mapping team?

- ○ No
- ○ Yes

22. [If more AI curricula, please select how many and move to the next page][47]

47 When adding more AI curricula, the questionnaire repeated questions six to 21 for up to 13 curricula.

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K-12 AI curricula

A mapping of government-endorsed AI curricula

Regulations on their own are insufficient to ensure AI as a common good for education and for humanity. All citizens need to be equipped with some level of AI literacy covering the values, knowledge and skills relating to AI. This report features key findings and recommendations of UNESCO's global survey on AI curricula for K-12. It reveals that only 11 countries have developed and endorsed K-12 AI curricula and another four countries have AI curricula in development. This is a strong call for Member States to develop AI curricula for K-12 students, and to build stronger mechanisms to validate non-governmental AI curricula offered to balance the private-driven approach. The report also reveals that the learning outcomes of AI curricula need to be more focused on fostering creativity in crafting AI technologies and on contextual ethics. Teacher training is key to ensure the implementation of AI curricula, and teachers need to be trained on designing and facilitating project-based learning which is the most commonly used pedagogical methodology in existing AI curricula. The report also advises an 'agnostic approach' towards AI brands and products when introducing domain-specific AI technologies.

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4 QUALITY EDUCATION

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Synthesis Report

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Education Sector

Education 2030

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Executive Summary

The '*International Forum on AI and the Futures of Education: Developing Competencies for the AI Era*'[1] was co-organized by UNESCO, the Ministry of Education of the People's Republic of China, and the National Commission of the People's Republic of China for UNESCO. Building on the Beijing Consensus, the Forum shared policies and practices regarding the role of AI in education, with a specific focus on defining the competencies required in the AI era, and strategies to prepare all people to live and work with AI effectively. Forum participants included government ministers and other high-level ministry officials from Member States, together with representatives of international organizations, NGOs and academic institutions.

Internationally recognized ethical principles to regulate AI for the common good

With Artificial Intelligence (AI) becoming increasingly pervasive and transcending national boundaries, all countries must work together to ensure that AI remains under human control and is designed and applied for the common good. In particular, it is essential that humans are protected from becoming victims of AI tools, and that AI is used to augment and amplify human capacities, not to replace them. This begins in education. Once the key human and technical AI competencies have been identified, school systems need to ensure that all students are well prepared for a world in which AI is ubiquitous.

The multiple and complex challenges associated with AI need to be properly considered. For example, AI is known to be sometimes biased; however, the cause is not always obvious. AI decisions might be biased because the human data on which it is based are biased, and/or because the algorithms applied by humans are biased. In other words, AI reflects and instantiates human decision-making, reinforcing the need for humans to step up and take responsibility and control. This is self-evidently important when AI is weaponized, or explicitly threatens human rights. However, it is also important when AI is used in everyday contexts: for example, to automate low-skill tasks which might have a negative impact on jobs, or in education which might compromise student cognitive development. Nonetheless, it is also important to recognize that, when understood fully and ethical by design, AI can also be used to uphold human rights – by, for example, protecting data privacy and security.

For many technologies, the comprehensive rules that we now take for granted took decades to develop, lagging far behind the development of technologies themselves. This is currently happening with AI. In fact, AI is developing so rapidly and has such potential to impact so widely that the development and enactment of regulatory frameworks localized for national contexts are becoming more urgent. However, AI by its nature transcends borders such that effective regulation will itself have to be transnational by design. Accordingly, we need international standards for data and algorithms, together with ethical governance and stewardship, all focused on protecting human rights. We need to ensure that the design of AI is accountable, transparent, and explainable – so that we know who has responsibility, what informed the decision making, and how the decisions were

[1] Detailed information about the Forum can be found at: https://en.unesco.org/news/international-forum-artificial-intelligence-and-futures-education-2020; and https://aiedforum.org

reached, so that society might judge effectively whether the AI and its use is both ethical and for the common good.

In particular, AI developers need to be regulated, especially those working in the public domain of education, because of the as-yet unknown impact of the AI on young developing minds. However, none of this is to suggest that AI should not be used in education or beyond. Rather, society needs to have a robust say in how and what AI is developed and applied, especially when this involves children and classrooms. To begin with, like all regulations, the proposed regulation of AI needs to be firmly grounded in robust ethics, such as that provided by UNESCO's *Recommendation on the Ethics of Artificial Intelligence*, due for consideration by UNESCO's General Conference at its 41st session at the end of 2021.[2] However, AI must also be considered in terms of the context in which it is being applied, be that automotive, health, entertainment, or other sectors. When AI is applied in educational contexts, this means that ethical principles specific to the field of education – around, for example, pedagogy, consent and agency – also need to be elaborated and addressed.

Developing AI literacy for all

Yet, regulations on their own are insufficient. The world's citizens also need to understand what the impact of AI might be, what AI can do and what it cannot do, when AI is useful and when its use should be questioned, and how AI might be steered for the public good. This requires everyone to achieve some level of competency with regard to AI. This includes the knowledge, understanding, skills, and value orientation, that together, might be called *AI Literacy*. AI Literacy comprises both *Data Literacy*, or the ability to understand how AI collects, cleans, manipulates, and analyses data, as well as *Algorithm Literacy*, or the ability to understand how the AI algorithms find patterns and connections in the data, which might be used for human-machine interactions. While there is growing attention to Data Literacy, *Algorithm Literacy* remains largely overlooked.

Countries are increasingly realizing the importance of developing AI Literacy among school students. For this, AI needs to be included in school curricula as an integral component of digital literacies, and alongside existing core competencies such as language and mathematics. AI Literacy also needs to be developed by all young people and citizens through lifelong learning programmes.

Preparing competencies for the AI era

AI Literacy involves a balance of human-oriented and technology-oriented competencies. The human-oriented competencies centre on the past, present, and possible futures of AI, the uniqueness of humans, the ethics of AI and its social impact, together with data justice and regulation. Technology-oriented competencies, on the other hand, centre on AI techniques, technologies and applications, and include the advanced AI knowledge and skills needed to create, manipulate, implement, and interpret AI. Accordingly, the teaching of AI Literacy needs to adopt both a subject-specific and an interdisciplinary approach. Specific curricula and courses in AI need to be established, covering both the human and technology aspects of AI, building upon existing ICT curricula and courses. In addition, the potential and impact of AI need to be considered in all school subject areas whether the sciences, humanities, or the arts.

[2] https://en.unesco.org/artificial-intelligence/ethics

These subject-specific and interdisciplinary curricula should draw on the AI school curricula developed by pioneering countries, and must be flexible, open, inclusive and continuously evolving. Multiple stakeholders need to be involved in the design of learning materials, such as AI-driven interactive textbooks, and teachers need to be appropriately trained. AI competencies could also be developed in extracurricular activities such as coding clubs and hackathons, as well as in lifelong learning programmes such as job-, career- and entrepreneurship-related training. Such integration would equip more children, young people and working adults to fully understand how to interact with AI systems, how to take informed decisions, and how to prepare for the social impact of the widespread use of AI on jobs, health, democracy and education.

Implications of the use of AI tools in schools

In addition to being an area of study, AI is increasingly being applied in education to support management, learning and assessment. Examples include AI to automate routine administrative tasks, to diagnose student competencies, and to offer learning content and feedback adapted to individual progress and miscomprehensions. However, current AI-driven education tools, although effective in some contexts, remain narrow. Most are constrained by the range of subjects that they cover, usually limited to mathematics and some sciences; by the pedagogical approach that they take, often at odds with approaches inspired by the learning sciences; and by their prioritization of machine-based interactions over human-human interactions. Both the potential and the limitations have yet to be fully identified, elaborated or addressed. Nonetheless, it is clear and widely agreed that AI should not replace schools or teachers. Instead, social interactions – between students and teachers, and between students and their peers – need to remain at the heart of learning. In addition, some existing AI tools may reduce student agency. It is important that students be supported to be active participants in the learning process and to take more responsibility for their own learning. Moreover, AI developers need to move beyond developing tools that aim or claim to teach better than teachers, to develop instead AI tools that augment teacher capacity helping them to become the best teachers that they can be.

Equitable and inclusive use of AI

Developments in AI and AI regulations have to be achieved without compromising human values, without undermining diversity, and without creating new inequities. In particular, an AI divide between countries must be avoided. For this, issues of infrastructure, especially internet connectivity, still need to be addressed, while all countries should work to become less dependent on the big technology companies. Accordingly, many of the least developed countries are calling on international organizations and developed countries to help enhance local infrastructure, to provide open-source AI tools and resources, and to ensure the local ownership of data generated in national contexts. Exemplar initiatives that demonstrate AI's potential to be inclusive include applications to support students who have disabilities or speak indigenous languages, as well as strategic and operational partnerships in Africa which are designed to address the digital divide and promote the equitable development and use of AI across the continent.

AI and gender equity

National authorities also need to ensure that AI contributes to achieving gender equity instead of widening the existing gender gap. In particular, this means ensuring that human rights, safety and

the integrity of girls and women are not compromised in the design of algorithms, data analytics and data-based decision making, nor at any stage of the application of AI in education. In most countries, structural factors, including the way in which societies are organised, laws are set, and economies function, constrain the participation of women in AI development. This must be redressed early in schooling. There should also be more emphasis on encouraging women to become AI researchers in universities and to train in AI skills, to help ensure that more women are represented among AI engineers of the future. Only if women are properly represented in the AI workforce can AI begin to be genuinely fair, inclusive and better reflect society. This is also true for other disadvantaged groups such as persons with disabilities and young people from the Global South.

AI and the futures of education

The Forum underlined the importance of reviewing the very purpose of education, together with the opportunity for real transformation, and the role that AI might play. It is widely acknowledged that current educational practices and educational environment are very rigid, and that the future of education should be more flexible and responsive to changing circumstances and innovation. National education authorities should identify what skills young people need to enable them to live and thrive in the new realities of a constantly changing world, and what digital transformation makes possible in the national and international context. In short, new education models are needed to put students at the centre, to move away from a focus on memorizing content, to integrate the digital and the analogue, and to foster human cognitive, socioemotional and critical skills, all of which might – with foresight and careful attention – be enabled by AI and other digital technologies.

Introduction to the Forum

One and a half years after the adoption of the *Beijing Consensus*[3] at the first *International Conference on AI and Education* held in Beijing in May 2019[4] and in the aftermath of the first COVID-19 education disruption, UNESCO together with the Ministry of Education of the People's Republic of China and the National Commission of the People's Republic of China for UNESCO co-organized the *International Forum on Artificial Intelligence and the Futures of Education* under the theme *Developing Competencies for the AI Era*.

Held over two days on the 7th and 8th of December 2020, the Forum successfully merged virtual sessions and physical meetings in Beijing to engage participants in dialogue about the pervasive use of AI in the future, and addressed the challenges associated with developing competencies for the AI era. It involved 80 speakers, including government ministers and other representatives from twelve Member States, together with participants from NGOs, the private sector, and international organizations, as well as leading experts. More than 2,000 participants from 33 Member States took part. The Forum was also livestreamed on YouTube (in English, French and Chinese) where it received more than 3,500 views.

The Forum opened with Ministers, Vice-Ministers, and State Secretaries from China, Croatia, Ethiopia, Slovenia, South Sudan, and the United Arab Emirates sharing their national experiences and programmes on AI and education. The second day included presentations by high-level representatives from the Ministries of Education and ICT of Cambodia, Kenya, Morocco, Qatar and Saudi Arabia, as well as Directors of regional and international organizations for education such as the Southeast Asian Ministers of Education Organization (SEAMEO) Secretariat, the Information for All Programme, and UNESCO.

A plenary session explored how AI competencies could be defined and developed in the context of the futures of education. Prominent AI experts discussed AI in schools, public policy and IT systems. A core focus was the importance for all countries to strengthen AI literacy among young citizens in order to ensure that AI serves the common good.

The Forum also included a session on AI and education in the context of China convening Chinese scholars, policy-makers and educators to share their perspectives on the Futures of Education, as well as three parallel sessions devoted to: (1) the integration of AI in curriculum and textbooks; (2) the application of AI in learning and teaching and how to regulate its effective and ethical use; and (3) supporting education development in African countries for the coming AI Era.

The Beijing Consensus

The Forum built on the *Beijing Consensus* which recommended that UNESCO explore the role of AI in education and mobilize the organization's institutes and networks to consider issues such as the integration of AI skills into ICT competency frameworks. The Beijing Consensus provides guiding principles and concrete recommendations in response to three fundamental questions:

[3] https://unesdoc.unesco.org/ark:/48223/pf0000368303
[4] https://en.unesco.org/themes/ict-education/ai-education-conference-2019

- How can education systems ensure the ethical, inclusive and equitable use of AI in education?
- How can education prepare humans to live and work with AI?
- How can AI be leveraged to enhance or reinvent education?

The Beijing Consensus also recognizes the distinctive features of human intelligence. It reaffirms UNESCO's humanistic and ethical approach to the use of AI with a view to protecting human rights and preparing all people with the appropriate knowledge, skills and values needed for effective human-machine collaboration in life, learning and work in the service of sustainable development. The Consensus also affirms 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 the educational process. In particular, it reaffirms that teachers cannot be displaced by machines. The Consensus affirms that the deployment of AI in classrooms and beyond should be in the service of people and seek to enhance human capabilities.

While recognizing the potential of AI to support and transform learning and learning assessment, it is important to note that evidence on the impact of AI in improving learning outcomes of subject-specific learning and the development of interdisciplinary competencies remains scarce. It is therefore important to carefully review efforts to integrate AI in school curricula, whether by teaching *about* AI techniques, teaching *with* AI tools, or by preparing young people for life in a world increasingly influenced by AI,

The Consensus also recommends that governments and other stakeholders among UNESCO's Member States consider implementing system-wide actions in response to the education-related opportunities and challenges presented by AI. In particular, it highlights the emergence of a set of AI literacy skills required for effective human-machine collaboration in the AI era.

COVID-19

The economic and social disruption caused by the COVID-19 pandemic has further heightened the complexity, uncertainty, and fragility of the world in which we live with its persistent inequities, social fragmentation, and political extremism. The disruption resulting from the pandemic has exposed the vulnerabilities of our societies and our education systems, and is further exacerbating the pre-existing learning crisis. Although all countries adopted some modality of remote learning in their national education response in the form of online platforms, TV and radio programmes and take-home packages, the coverage was extremely uneven and millions of learners were left without any access to formal education.[5]

Recent survey data clearly indicates that learning loss has been more acute in low- and lower middle-income countries, than in high-income countries.[6] Disengagement and the risk of drop out is highest for the most vulnerable with the number of children out of school likely to increase by at least 24 million as a result of the pandemic.[7] In response, UNESCO has taken a holistic approach to strengthening international cooperation to support Member States to enhance distance learning

[5] https://en.unesco.org/covid19/educationresponse
[6] https://data.unicef.org/resources/national-education-responses-to-covid19
[7] https://www.unicef.org/press-releases/children-cannot-afford-another-year-school-disruption

solutions, support the safe reopening of schools, and to reimagine more resilient learning systems for the future.

The Futures of Education initiative

The current crisis also highlights the urgency of charting possible futures of education. Recognizing that knowledge and learning are humanity's greatest renewable resources for responding to challenges and inventing alternatives, UNESCO launched the *'Futures of Education'* initiative[8] in late 2019 before the outbreak of the COVID-19 pandemic. The initiative aims to rethink the role of education, learning and knowledge in light of the tremendous challenges and opportunities of multiple possible futures. Such re-visioning of knowledge, education and learning is more relevant than ever. Indeed, accelerated technological transformations over recent years, in particular in the field of AI, and their rapid deployment in work, life and education have profound implications for the future. AI is largely believed to hold transformative powers in reshaping human society and life, and will likely bring human history to a new era where we need to live and work together with AI. These transformations represent both challenges and opportunities that need to be carefully examined. The *'Futures of Education'* initiative aims to generate discussion and action on the role of education, knowledge and learning in view of the predicted, possible and preferred futures. The Forum provided an opportunity to discuss these implications and the transformative potential of AI on education.

[8] https://en.unesco.org/futuresofeducation

Ensuring inclusive, equitable, and ethical use of AI: A global challenge

MODERATOR

H.E. Mr Xuejun Tian
Vice Minister of Education and Chair of the National Commission of the People's Republic of China for UNESCO, People's Republic of China

SPEAKERS

H.E. Mr Baosheng Chen
Minister of Education, People's Republic of China

H.E. Mr Agapito Mba Mokuy
Chairperson of the Executive Board, UNESCO

Ms Stefania Giannini
Assistant Director-General for Education, UNESCO

The *'International Forum on Artificial Intelligence and the Futures of Education'* began with keynote speeches by **H.E. Mr Baosheng Chen**, Minister of Education of the People's Republic of China, **H.E. Mr Agapito Mba Mokuy**, Chairperson of the UNESCO Executive Board, and **Ms Stefania Giannini**, UNESCO Assistant Director-General for Education. Each of these speakers spoke about the global challenges of ensuring the inclusive, equitable, and ethical use of AI in education.

H.E. Mr Baosheng Chen started by mentioning how in the past year the world had experienced the enormous impact of COVID-19, which has been rarely seen in human history and is still raging across the world. He further acknowledged that the pandemic has dealt a heavy blow to education worldwide, and governments and the education sectors of various countries have responded with all-out efforts by introducing online education on an unprecedented massive scale. New technologies such as AI have shown tremendous potential to transform education. The pandemic will end one day, but the world will be a different place. Education will not be the same either. Education bears on the future of humanity. It is our shared responsibility to plan the development of education with a vision for the future.

The new round of scientific and technological revolution and industrial revolution is happening right now, characterized by the extensive application of new technologies such as AI, cloud computing, blockchain, 5G and so on. The intelligent age is dawning on us with changes that are about to transform human society. In this context, it is the mission of education to help equip each and every one with the skills and abilities to capitalize on the new technologies for better lives.

Accordingly, we need to accelerate the development of higher-quality education. The content, methods, assessment, teaching platforms and qualities of teachers all need to be reformed to ensure that every learner can access quality education and achieve the well-rounded development they need to get themselves ready for the new era.

We need to accelerate the development of more equitable and more inclusive education. While technological advancement may be good for humanity, it may also widen the gap between different groups. The negative impact of the digital divide has been made evident by global online teaching during this pandemic.

We also need to accelerate the development of personalized education. Over 2,500 years ago, the ancient Chinese educator Confucius put forward the concept of education based on the personal traits of each individual. Progress in AI has provided the possibility to promote personalized development. We should apply the new technologies to create new smarter learning environments

better suited to each individual's needs. We also need to accelerate the development of more open and flexible education. Human society is developing faster and faster. More breath-taking changes will take place as we enter the intelligent age. To keep up with the times, education needs to be more open and flexible.

In the past five years, the Government of China has been actively implementing the UN's Education 2030 Agenda for Sustainable Development.[9] Priority has been given to education as part of economic and social development. China's Education Modernization 2035 and the Five-Year Implementation Plan have been released and enacted.

At the Fifth Plenary Session of the 19th CPC Central Committee convened at November 2020 overall arrangements were made for the next five years[10] and for the modernization of China by 2035.[11] Such goals as building a high-quality education system and a country strong in education have been clearly set. Facing the new era and driven by reform, China will spare no effort to implement the *'Education 2030 Agenda'* and accelerate the modernization of education. First, we will put more emphasis on improving education quality. Centring on the core competencies, we need to set the standards of education quality that cover all the stages, levels and types of education, and put in place sound standards for all subjects, disciplines and the standard for physical health as well. Second, we will strive to promote equity and inclusiveness. We will improve the mechanism to realize more coordinated education development between urban and rural areas and across regions. Third, we will focus on the application of new technology. We will keep deepening our understanding of how learning should be done, use new technologies such as AI to create new teaching methods, and support differentiated teaching and personalized learning with such technologies as educational data mining, learning analytics and deep learning. Fourth, we will further open up our education. We are firmly committed to the opening up of education and we keep strengthening exchanges and cooperation with various countries and international organizations including UNESCO.

COVID-19 has made it evident that humanity is a community with a shared future. To embrace the age of intelligence, we need to join our hands and pool our efforts. China stands ready to continue to organize international meetings on AI and education, and work together with all sides to follow through on the *'Beijing Consensus'* adopted at last year's conference.

H.E. Mr Agapito Mba Mokuy began by highlighting that the world of tomorrow will depend highly on AI. Ignoring this reality will be a grave mistake and will imply a total disconnect from the reality of the 21st century. With the advancement of technology, new technical and social systems, organizational structures, managerial practices, and competencies and skills are needed. He then acknowledged that the multiple steps undertaken by the Government of China in cooperation with international bodies such as UNESCO to lead the way in research, training and advancement in AI as well as the inclusion of developing countries, are of extreme significance and should be applauded. To enable all nations to remain competitive in tomorrow's world, one important action that could be recommended is to ensure universal access to the internet. UNESCO should lead an international campaign to ensure that this becomes a right – otherwise the gap between the haves and the have-nots will continue to widen.

[9] https://www.fmprc.gov.cn/mfa_eng/topics_665678/2030kcxfzyc/P020190924780823323749.pdf
[10] https://en.ndrc.gov.cn/newsrelease_8232/201612/P020191101481868235378.pdf
[11] http://www.gov.cn/xinwen/2019-02/23/content_5367987.htm

UNICEF and ITU have recently prepared a report entitled *'How many children and young people have internet at home?'*. This report looks at digital connectivity during the COVID-19 pandemic, and estimates that two thirds of children and young people aged 25 years or less do not have an internet connection in their family home.[12] In fact, while 87% of children have internet connectivity at home in high-income countries, the figure is only 6% in low-income countries. This means that 2.2 billion children and young people worldwide below 25 have no internet at home, of whom 1 billion live in Asia or Africa. H.E. Mr Mba Mokuy reflected that one cannot emphasize the gravity of this reality, particularly in the era of technological advancement and AI. The COVID-19 pandemic has shown that multilateralism is the way forward.

The *'Beijing Consensus'* recommends that UNESCO take a leading role in AI and education, mobilizing the organization's Institutes to the specific purpose of integrating AI skills into ICT competency frameworks. It also recommends that UNESCO further expand its cooperation in the field of AI with relevant partners. Currently, no organization is solely responsible for this sector. This is the reason for the proposal for China to establish a Category 1 Institute in the field of AI and education. This will focus on South-South cooperation and will aim to assist developing nations that desperately need connectivity to the internet, curriculum reform for the AI era and training. These objectives should not be secondary to the mission of the Institute.

Ms Stefania Giannini reminded participants that this Forum built on the great success of the first International Conference on AI and Education, co-organized by UNESCO and the Chinese Government in Beijing in 2019, which led to the adoption of the *'Beijing Consensus'* – the first international consensus on AI and Education. The *Beijing Consensus* reaffirms UNESCO's humanistic and ethical approach to the design and use of AI, including in education. AI should be designed in the service of humanity; it should serve to enhance human capacities for sustainable development, and for a better society. To this end, UNESCO is leading the development of *'Recommendations on the Ethics of AI'*[13] to maximize the benefits of AI for human development and mitigate potential risks.

In the framework of the humanistic approach to AI, the *Beijing Consensus* recognizes the uniqueness of human intelligence and human competencies in the face of AI. This is in line with the lessons we have learned from our response to the COVID-19 crisis. Accordingly, the core aim of the Forum was to define human AI competencies – the knowledge, skills and values needed for effective human-machine collaboration in life, learning and work. In dedicating the Forum to the theme of *'Developing AI Competencies'*, UNESCO called on Member States to recognize the increasing importance of developing AI literacy and AI competencies for all citizens. The aim of the discussions was to facilitate knowledge sharing on how AI competencies can be developed in schools and universities, and through lifelong learning opportunities with particular attention to the empowerment of women and young people.

According to our scoping studies, many Member States are progressing in developing curricula on AI competencies at different education levels, with China being one of the leading countries. However, while AI transcends domain boundaries, our curricula have not. We note that a technology-oriented approach has been typically taken towards AI skills training, and AI is usually only taught as part of

[12] https://www.unicef.org/media/88381/file/How-many-children-and-young-people-have-internet-access-at-home-2020.pdf
[13] https://unesdoc.unesco.org/ark:/48223/pf0000373434

the computing curriculum. Human and in-depth ethical questions are too often ignored. In fact, when teaching art or music, perhaps we should also consider the works of art created by AI systems?

UNESCO is drafting a framework for AI competency development to guide a more human-centred curriculum paradigm. The development of forward-looking AI competencies should be anchored under the framework of the futures of education and learning. Future learning systems should integrate these competencies as core sets of skills for all learners.

The UNESCO *'Futures of Education'* initiative aims to rethink the role of education, learning, and knowledge in light of the challenges and opportunities of the possible futures. With the National Commission of the People's Republic of China for UNESCO, we are co-organizing a special Consultation Session on the Futures of Education.

Among other areas, accelerating technology advancements, particularly in the field of AI, have profound implications for the future of education. If we are to secure a safe and inclusive digital future for all, as stated by UN Secretary-General Mr António Guterres, we need to reaffirm that AI must be used as a public good. The deployment and use of AI in education must be guided by the core values of UNESCO: inclusion and equity.

UNESCO has published two editions of a compendium featuring more than 80 projects on using AI tools to advance inclusion and equity in education. In our case studies, we showcase AI applications designed for children with autism and other disabilities; the use of AI to detect and prevent school dropout; AI applications that can support self-paced literacy; and the use of AI to empower teachers and teacher training instead of replacing or displacing teachers. Meanwhile, the 2019 edition of the UNESCO *'Prize for ICT in Education'* recognized AI tools for diagnosing children with reading disabilities.[14] During the Forum, we also heard about scalable AI applications promoting inclusive learning in Africa, and AI tools supporting the learning through indigenous languages.

Having said that, it is alarming that almost no regulations have been enacted to address the ethical issues raised by the use of AI in education. Without regulations, AI is likely to exacerbate the marginalization of vulnerable groups and amplify discrimination. There are also growing cases of the misuse of students' personal data by AI companies and of the introduction of AI in classrooms intruding on students' natural behaviours and teachers' human rights. Critically, the use of AI in education will only benefit all if – by design – it enhances human-centred pedagogical principles, and respects ethical norms and standards.

The deployment of AI in classrooms and other learning settings should be centred on the genuine needs of teachers and students, rather than on commercial imperatives. Accordingly, although increasing numbers of tools appear to offer solutions to improving educational attainment, it is important to note that evidence for the positive impact of AI on learning remains scarce. This is why Member States should encourage more research to determine how AI might best be used to improve the quality of learning. Furthermore, the international education community should do more to review the profound impact of AI on education provision and management, teaching, learning, and assessment – including a charting of the potential risks.

[14] https://unesdoc.unesco.org/ark:/48223/pf0000373477

National strategies on AI and education

MODERATOR

Mr Sobhi Tawil

Director, Future of Learning and Innovation Team, UNESCO

SPEAKERS

H.E. Ms Simona Kustec

Minister of Education, Science and Sport, Slovenia

H.E. Mr Hussain bin Ibrahim Al Hammadi

Minister of Education, United Arab Emirates

H.E. Mr Fuzhi Zheng

Vice Minister of Education, People's Republic of China

H.E. Mr Gabriel Changson Chang

Minister of Higher Education, Science and Technology, South Sudan

H.E. Dr Engineer Getahun Mekuria

Minister of Education, Ethiopia

Ms Ivana Franić

State Secretary, Ministry of Science and Education, Croatia

H.E. Mr Hussain bin Ibrahim Al Hammadi, Minister of Education, United Arab Emirates, began with a reflection on the impacts of COVID-19 on education. He reminded participants that no one had predicted a pandemic that would lead to the worldwide closure of schools. In fact, the pandemic had also exacerbated many problems that already existed. As **H.E. Ms Ivana Franić**, State Secretary, Ministry of Science and Education, Croatia, explained, even when schools were open, millions of children still could not read, write or do basic mathematics even after several years in school. This learning crisis is widening social gaps instead of narrowing them. Around the world, too many young students who are already disadvantaged by poverty, conflict, gender and disability reach young adulthood without even the most basic life skills.

H.E. Mr Gabriel Changson Chang, Minister of Higher Education, Science and Technology, South Sudan, added another level of complexity. Traditionally, education has been seen as a social, cultural phenomenon, and a conduit through which a community's values, norms and identity are passed from one generation to the next. However, now that educational resources are becoming increasingly global and students are virtually identifying more than physically identifying themselves, how can community norms and culture be preserved? Put another way, can Sustainable Development Goal 4, which requires quality and equity in education, be achieved in such an imbalanced situation where many developing countries are without the necessary technology or infrastructure?

Nonetheless, many people have predicted that a new education will emerge gradually as a result of the fourth Industrial Revolution and AI. This new way of learning will require a more open learning environment and a 'learning society' in which everyone can learn whatever, whenever and wherever they want. For this, the COVID-19 pandemic has been an accelerator because it has shown the world in a very short time what can be done using technology.

In fact, AI has become increasingly important and more noticeable even in low-income countries, although multiple infrastructure issues remain a major barrier. Nonetheless, AI has the potential to benefit many sectors, including education and training, and to contribute to the way we build the future of our common values. It is essential that AI should always be in the service of humanity, yet it brings with it multiple issues and risks that need to be debated and addressed. For example, as **H.E. Ms Simona Kustec**, Minister of Education, Science and Sport, Slovenia, pointed out, it is possible that around half of all existing jobs will disappear over the next 10 to 12 years, bringing massive changes to society.

H.E. Mr Fuzhi Zheng, Vice Minister of Education, People's Republic of China, highlighted that the AI era has brought about new trends in social structure and everyday life, thus propelling education to adapt to these changes. The digital age has witnessed closer interpersonal connection and human connection with material things. As a result, humans need to be equipped with solid information literacy and understanding of new ethical and moral issues. AI can enable personalized learning anytime, anywhere and potentially for anyone. It also requires a lifelong learning system that is responsive to the ever-evolving learning environment. In this context, school education needs to, first and foremost, set up clear goals for talent development across emerging subject areas. These include information literacy which allows students to thrive in a digital age, higher-order competences (critical thinking, innovation, reflection and introspection) enabling them to navigate ambiguity and uncertainty, as well as ethical standards to promote conviviality, social inclusion and cultural diversity.

Second, H.E. Mr Zheng added, in order to prepare students for the intelligent era, schools need to improve the curricular system, teaching materials and pedagogy. In addition to integrating AI-related topics in school curricula, efforts should also centre on developing essential qualities and character-building, with a view to cultivating innovative and versatile talent with practical skills. The suitable teaching materials are those close to real life, inspiring innovation and attuned to emerging trends. Whilst ensuring pedagogy is effective, schools also need to integrate innovative teaching methods, such as smart devices for distance and mixed learning, and promote personalized learning paths. Third, it is imperative that education evaluation shifts from knowledge-based to quality-based. With essential qualities at the core, evaluation should be flexible, multi-dimensional and well-embedded in the learning process. A feedback and adjustment mechanism involving students proves to be instrumental. At the same time, schools could adopt new evaluation methods, such as using intelligent learning system based on cloud computing and big data. Supervision and assessment should cover the entire learning process, all grades and all factors (e.g. knowledge, skills and values). It is also beneficial to set up a regional, multi-stakeholder evaluation system, as well as to support and improve the use of evaluation results with the help of AI and new technologies.

The potential of AI in education has been researched, debated and discussed for nearly 20 years within the academic community. What everybody agrees on is that AI has changed drastically in the last few years and will likely continue to do so, bringing risks as well as opportunities for education – especially now in the context of the COVID-19 crisis. Therefore, we need to proceed vigilantly and prudently into a new educational environment where AI is used to support the learners and teachers and where we also prepare learners for a future where AI plays an increasing role.

AI is also shifting the theories, focuses, priorities and practices of education. One area experiencing change is the role of teachers. The traditional view of teachers as controllers, transmitters and processors of knowledge seems to be fading away. Robots and some computer programs are increasingly taking over this role and have proven to be effective tutors and mentors to learners to some degree. AI technologies are becoming the brains driving the future of education processes and progress. For example, the role of teachers in higher education is being increasingly limited to supporting learners in seeking, finding and integrating information, and supervising their collaborative work as independent learners and thinkers. However, as the role of AI increases, we still need human teachers, whether at universities or at lower levels, to work in unison with AI. The focus should be on how we assist teachers to help learners to become better instead of replacing them.

We must also ensure that AI in education does not result in a growing achievement gap. This can only be achieved if the human role continues to be central, if all stakeholders are involved in the design of this future of learning, and if the process is transparent. For example, to judge whether a student is ready for a more challenging task, it will still be necessary to have teachers of high professional and moral standards. Speakers also acknowledged that, while the potential benefits of using AI to tackle the entrenched injustices faced by learners across the globe are profound, the risks posed by AI in education are significant. Accordingly, learners, educators and societies as a whole should without question be cautious about introducing AI into any form of learning environment.

The growing impact of AI on society also means that all citizens need to be taught about AI. **H.E. Dr Engineer Getahun Mekuria**, Minister of Education, Ethiopia, suggested that ministers of education and UNESCO should commit to a total overhaul of the curriculum, starting from elementary school up to university. AI is fundamentally changing the skills needed in society, while human life-skills need to be closely related to the economic goals and human well-being of a future knowledge society. There are three types of skills:

- skills to develop AI which requires highly skilled individuals with solid computer science backgrounds;
- skills to work with AI which requires problem solving and innovation; and
- skills for people to live with AI.

In summary, participants agreed that we should redesign the curriculum system to highlight the development of core competencies. The curriculum is not just an education and teaching system, but it also reflects the goal of talent cultivation and so should be designed to reflect that goal. At the same time, attention should be given to big concepts, big ideas and comprehensive things in order to reconstruct the content of the curriculum and to improve the presentation of the concepts. In particular, it is essential to help teachers shift from focusing on imparting knowledge to focusing on supporting student self-development.

A renewed emphasis should also be placed on the cultivation of proper values, essential characteristics and core competencies that can enable lifelong personal development. First, attention should be paid to empowering students with information awareness, computational thinking and digital learning abilities, so they can survive and thrive in the digital world. Second, attention should be paid to the cultivation of higher-order competencies such as critical thinking, the courage to explore and innovate, and the ability to reflect and introspect. This can help students cope with the uncertainties of the future world. Third, attention should be paid to reinforcing a sense of social responsibility. We should stress the importance of a self-disciplined, interdependent and teamwork sense of responsibility, and we should equip students with attitudes founded on ethical standards so as to help them understand the concept of a community with a shared future that is open and inclusive. However, the main competencies that need to be built are now not for the *development* of AI but for the *use* of AI. So, how can governments build an 'AI ready' workforce, and how can we support citizens with educational systems and services as new Artificial Intelligence technologies emerge in the future? This is why Artificial Intelligence needs to be part of both formal and informal education in the same way that digital competencies were in the 1990s, but cutting across disciplines.

In order to cultivate talent for the AI era, it is important to start to build a new course and textbook system, undertake remote teaching reforms, and change the approaches of talent cultivation

followed by educational institutions. Teaching materials should be chosen based on the need to develop the core competencies of students based on their life experience and situational social developments. In addition, focus should be given to improving teaching methods to foster core competencies in students. Research in the Learning Sciences should be strengthened to explore new teaching methods based on the laws of learning to make learning more effective.

Finally, all Member States have to cooperate and share ideas because these are not local issues but global ones. There are already some examples of international collaborations. For example, Slovenia has established the first *'International Research Centre on Artificial Intelligence'* (*IRCAI*)[15] under the auspices of UNESCO, which aims to explore how education systems can ensure the ethical inclusion and equitable use of Artificial Intelligence in education, and to help Member States address the recommendations of UNESCO's *'Beijing Consensus'*. A key focus for IRCAI is to develop global collaboration in research on AI and education.

National Strategies on AI and Education: Key Messages

- AI has the potential to benefit many sectors, including education and training, and to contribute to the way we build the future of our common values.
- Transformation cannot happen without proper physical infrastructure.
- AI should be in the service of humanity, but it brings risks as well as opportunities so we need to proceed prudently.
- AI is shifting the theories, priorities and practices of education.
- Students need skills to develop AI, skills to work with AI, and skills to live with AI.
- AI-powered learning should address, not increase, inequities.
- The traditional view of teachers as transmitters of knowledge is changing. However, we still need human teachers. The focus should be on assisting teachers not replacing them.
- Ministers of education should overhaul the curriculum from elementary school up to university.
- All stakeholders should be involved in the design of futures of learning.
- The curriculum should empower students with information awareness, computational thinking and digital learning abilities, higher-order competencies such as critical thinking, the courage to explore and innovate, and the ability to reflect and introspect, and ethical standards.
- To respond to the new trends, education evaluation should shift from knowledge-based to quality-based, while adopting flexible, innovative, and technology-enabled methods of evaluation, as well as developing multi-stakeholder and comprehensive supervision and assessment mechanisms.

[15] https://ircai.org

AI and the futures of education

UNESCO's flagship programme on Futures of Education[16] in the context of forthcoming AI era was explored by Chinese scholars. To begin with, it was suggested, it is necessary to review the very purpose of education and its organization in terms of SDG 4 and the Education 2030 Agenda, and in the context of today's digital transformation – especially as education is a key pillar for social and economic sustainable development. This need to rethink education has been reaffirmed by the COVID-19 pandemic. However, most efforts worldwide over the past months have focused on addressing the disruption to face-to-face education. Instead, we must do more than that. We must seize this opportunity for real transformation to ensure that the future of education involves lifelong learning for all, is accessible to and adapted for the needs of everyone, and responds to society's real needs.

Rather than relying on first industrial revolution models, students should be at the centre of education. Indeed, we need to leverage the advances made possible by digital technologies, so that education is no longer be about memorizing content but instead focuses on 21st century skills like creativity, helping prepare students for the future that this transformation makes possible.

However, education is moving further and further away from the reality that

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[16] https://en.unesco.org/futuresofeducation

surrounds it. The current educational environment is very rigid and not in line with a constantly changing world. In addition, whenever curricula are reviewed, new content and themes are added, overloading teachers and students with more content to cover. Instead, it is important to lighten the curricula and to focus on what is really important and necessary for our students to learn. The curriculum should be adapted to current needs, and should involve new approaches that apply different strategies rather than being standardized. It should be flexible to enable students to both acquire and produce new knowledge. We need to understand what skills our young people will need to enable them to adapt to the new realities. We need to know how to prepare appropriate responses; and we have to design education to meet these complex challenges. In short, if we are to move forward successfully, it is necessary to redefine 'with whom' to learn, 'where' to learn, 'what' to learn and 'how' to learn.

Yet, all of this is taking place in an increasingly complex and uncertain world transformed by new technologies, which are posing serious challenges to education. Because of these new technologies, new jobs will emerge, and there will be young entrepreneurs and business innovations. The challenge will be to respond to these developments in our education systems to develop new educational offers based on emerging technologies. Accordingly, new education models are needed, possibly enabled by AI, IoT, Virtual Reality (VR)/Augmented Reality (AR), blockchain and big data analytics.

In particular, many have identified the potential of AI for sustainable development, and have highlighted the possibility of connecting education to AI in order to best serve the learners' learning interests. AI is essentially a tool for increasing human capabilities. We now need to think how AI might be developed for the common good, and how it might best be introduced to educational contexts. The AI has to be embedded in order to promote the development of each individual student, for instance their critical thinking skills, and might provide students with several pathways to learning. Achieving this will require partnerships with different stakeholders in order to build a consensus together with programmes for training teachers to help them address the many challenges. In this AI era, we need to analyse the skills that will be key to our changing contexts, redirect learning so that students acquire the knowledge that they need, make digital resources and new ways of learning accessible in remote areas, modernize teacher training so that they are able to interact effectively with these systems, and ensure that the focus remains on the student.

We also have to recognize that in some limited respects, AI is more capable than humans. It will replace humans in repetitive tasks, so it is likely to replace humans in some professions. However, the likelihood that AI will replace teachers is low due to the characteristics of the role. Even with such a revolution, schools will not disappear. Instead, AI could enable teachers and schools to solve core problems such as the difficulties of access to education in remote areas by connecting online teachers in one place and students in another. It could also help change current approaches and improve teachers' skills, which all too often fail to meet the needs of students, focusing it on areas such as creativity and involving social interactions and collaborative learning. AI will also help teachers in routine tasks, for example in the context of marking and assessment, freeing them for the really important tasks such as monitoring pupils' learning. AI could also be central to supporting students who have disabilities such as those who have sight or hearing problems.

Although we are still in the time of weak AI, AI already makes individualized learning possible by means of intelligent systems and helps decision-making by means of data. But the analogue world of

education will remain, so we need to integrate both the digital and the analogue in future education provision. Also, very importantly, we need to ensure digital inclusion for everyone, and effect a balance between the human and technological aspects of technology-driven education. Schools also need to consider what skills will be needed by our students, as AI increases its impact on the world.

AI and the Futures of Education: Key Messages

- We should investigate how to best integrate AI in education.
- We should use AI to empower and enhance education.
- We should discuss the future of education and redefine it in the context of the digital transformation
- We should define the core competences and skills that our students will need in the future.
- We should ensure that AI is developed to assist teachers and not to replace them.
- We should provide every student with an AI Companion and every teacher with an AI Assistant.
- We should make bridges between the digital and the analogical worlds.
- We should develop platforms that support both online and onsite (face to face) educational approaches.
- We should address the ethical and privacy questions raised by the use of AI.

Defining and developing AI competencies

A key question that now needs to be addressed is how AI will shape the future of humanity and education. Answering this involves reviewing the implications of AI to reimagine knowledge and education, guided by the principles of inclusion and equity in access to quality learning opportunities.

Humans have an innate ability to develop a 'theory of mind' – the ability to attribute mental states to others, which we develop through interactions with other humans. It is an extraordinarily sophisticated ability which, if it fails to develop, can lead to severe difficulties in adjusting and working in society. Given the growing impact of AI, we now need to work towards teaching young people how to develop a theory of the artificial mind. In particular, we need to teach the difference between the human and the artificial mind. Such skills will require an understanding of computational thinking but also an understanding of how AI ticks, gaining insights into what it can offer and what it cannot, all from a human perspective. The point is that humanity is more than intelligence. Accordingly, it is vital to develop an appreciation of our humanity that goes beyond mere intelligence, and the societies that educate the next generation to take control of AI and be creative will be those that will prosper the most.

We need to understand what AI can and cannot do because it is increasingly being used on a daily basis and is impacting our decision making throughout our lives. For example, online platforms that use AI, such as YouTube, are affecting schools and young people in secondary and primary education, having an increasingly significant impact on them. In fact, these platforms in some ways are actually increasing a new digital divide – between those who understand and those who do not understand AI. Working towards the AI curriculum means focusing on those human skills like self-regulation, which is a skill that allows us to monitor and guide our own behaviour. From the 'human-in-control' perspective as promoted by

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the European Union, humans should take the decisions while they use and monitor the data provided by the machines. The human ability to control and monitor AI is therefore essential, and humans need to understand how AI functions in order to do that.

Accordingly, AI has to be included in the curriculum, so that all citizens can understand how we interact with AI systems and can therefore take informed decisions. While AI can be a tool for good helping improve health, education and culture, there are also many risks and many issues. Risks include those around biases, manipulation and fragmentation, while the issues centre on transparency, data ownership, privacy and human rights. In fact, there are many challenges when considering using AI in educational contexts. For example, the use of AI to monitor who has submitted their work raises issues of surveillance. Other issues centre on who is going to govern the AI algorithms, whether teaching is going to focus on data, and whether AI is really equal in terms of gender. Clearly, AI can be a useful tool. For example, AI is used in Shanghai to support teaching, learning, assessment and evaluation. The experience from Shanghai shows that when the technology is secure, reliable and controlled, AI can be very helpful. In particular, learning is personalized, while AI has been used to track learning behaviours, to record and analyse the processes, and to recognize the obstacles that different students might face. AI can also improve the efficiency of teachers and to detect the competencies of students. Other examples include: TAL Education Group developed an AI and education solution for China's Ministry of Education which catered for thousands of students and teachers during COVID-19; a technology that integrated voice recognition and voice evaluation technologies to help students from ethnic minorities to learn Mandarin; and a massive database of student profiles. This solution recorded what the students learned, what they had not learned, and their motivations. Analysing the data generated digital student profiles that accurately identify and evaluate the precise learning trajectories and potential of individual students.

Nonetheless, there are also privacy issues, and problems around ethics, bias and inclusion. For these reasons and more, we need to establish rule-based governance just as we did following the arrival of the first motor cars. Most importantly, it is necessary to enable all citizens to understand the interaction with our AI systems, and to take properly informed decisions in our lives. But this will only work if we ensure that AI is accessible and inclusive, that it uses properly representative data and avoids biases, and that it is designed for the global common good.

For all of this, the roles of education, schools and universities, teachers and teaching, are paramount. UNESCO presented a project on developing AI competencies with a focus on teaching AI at schools.[17] Three interlinked action lines were proposed:

- an AI Skills Framework for K-12 students, involving learning objectives, teaching methodologies, and teacher training;
- resources for teachers to use to teach their students about AI, for which UNESCO is developing the 'Teaching AI for K-12' portal; and
- support for countries to develop their own curricula, including workshops and support for curriculum development.

Four categories of AI competencies were proposed:

- human-oriented competencies, such as the uniqueness of human intelligence, the social and ethical impact of AI, and data justice and regulation;
- computational thinking AI competencies, including representation and reasoning, algorithms

[17] Teaching Artificial Intelligence for k-12: http://teachingaifork12.org

and coding, and engineering and design thinking;
- technology-oriented competencies, including AI techniques, AI technologies and AI applications; and
- maker-oriented competencies, designing AI applications and contextual data/algorithm-based problem solving.

These competencies can be developed at three levels: national inter-sectoral, including identifying the appropriate AI competencies, and developing a funded master plan; the education sector, including developing curriculum, textbooks and assessment, and training teachers; and AI literacy under lifelong learning involving non-formal and informal initiatives such as coding clubs and hackathons.

From another perspective, AI literacy involves:

- a comprehensive set of AI knowledge, including what AI can do and what it cannot do, and the critical role of humans in all AI achievements;
- AI skills, including creating and using AI; and
- values, including when AI is useful and when it should be questioned.

The aim is to provide a reference upon which Member States can build curricula that respect their national contexts. The UNESCO AI guiding framework addresses the human-oriented AI competencies that must be included in any effective curriculum. These include AI past, present and possible futures, the potential of AI, the ethics of AI and its social impact, and data justice and regulation. Meanwhile, the framework also addresses technology-oriented AI competencies. These include AI techniques, for example symbolic AI, machine learning, and Bayesian networks; AI technologies, for example perception, creation, and agents; and AI applications, for example autonomous transport, AI in education, and AI in medicine.

One approach is that taken by Kids Code Jeunesse, which has developed a wide range of resources to promote *'Algorithm Literacy'*[18] and to help students learn about AI. These resources cover traditional programming and machine learning, computational thinking and human values, and are designed to be used by teachers with their students especially as triggers for discussions. One recently developed resource is an animated video about algorithms.[19] This shows how understanding algorithms can help us to make decisions and to retain the power over AI. Key messages include that AI is not always visible, algorithms are not always right, ethical issues are always involved, and emerging literacies are needed.

Although many details are not publicly available, there currently exists only a few national curricula designed to support AI literacy, many of which are still in development. In other countries, this work has been left to the private sector. However, most AI curricula that exist appear to be almost entirely technology-oriented, although usually with a nod to ethics; whereas a robust AI curriculum must be both human-oriented and technology-oriented by design. In fact, the human aspects of AI must be threaded throughout the curriculum, and not just an after-thought. One country that has made significant progress is the Republic of Korea, which emphasizes that AI competencies should include human-intrinsic competencies such as cognitive skills, as well as a deep understanding of human uniqueness. Nations need to ensure that human capabilities are augmented with intelligent machines, as AI doesn't replace humans but complements and amplifies human functions.

[18] https://algorithmliteracy.org
[19] https://youtu.be/46AcviSU9Rg

Defining and Developing AI Competencies: Key Messages

- Young people need to develop a theory of the artificial mind, and to understand the difference between the human and the artificial mind.
- All countries need to achieve AI literacy, comprising a comprehensive set of AI competencies.
- From one perspective, AI competencies include: AI knowledge, what AI can do, and what it cannot do; skills, creating and using AI; and values, when AI is useful and when it should be questioned.
- From another perspective, AI competencies include: human-oriented competencies, computational thinking AI competencies, technology-oriented competencies, and maker-oriented competencies.
- Only a few countries have developed national curricula to support AI literacy.
- Most AI curricula are technology-oriented, whereas a robust AI curriculum must be both human-oriented and technology-oriented by design.
- A key human competency is self-regulation. Humans should take the decisions while they use and monitor the data provided by the machines.
- The human aspects of AI must be threaded throughout the curriculum, and not just an after-thought.
- UNESCO has been working with experts to develop a guiding framework of AI competencies, to provide a reference upon which Member States can build curricula that respect their national contexts.

Promoting equitable use of AI in education and support Priority Africa

AI is both a centrepiece of the new industrial revolution, and a carrier of technological progress that is changing societies and economies throughout the globe. However, AI is experiencing uneven development in Africa because the institutional, economic, and social conditions in many areas across the continent do not always create an enabling environment to unleash its potential. Accordingly, as **Mr Firmin Matoko**, Assistant Director-General for Priority Africa and External Relations (PAX/AFR), UNESCO, reaffirmed, it is important for African countries to develop AI skills and AI strategies for education and for improving life more broadly by means of a pan-African shared vision and international cooperation.

In light of these challenges and opportunities, PAX/AFR organized the first *'High-Level Forum on Artificial Intelligence in Africa'*, held at the Mohammed VI Polytechnic University in Benguérir, Morocco, which took place in December 2018.[20] It highlighted the many challenges and opportunities related to the development and use of AI in Africa. Several ministers, more than 30 Ambassadors to UNESCO, and around 500 international experts participated in this event. Building on the achievements of the Morocco Forum, this session aimed to foster constructive discussions on how new technologies should be leveraged

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[20] https://en.unesco.org/artificial-intelligence/africa-forum

through South-South dialogue and academic cooperation to accelerate the development of education in Africa, and to ensure that the continent benefits from AI.

Education is essential for the development of humanity, while the COVID-19 pandemic has put education to the test. However, this is also an excellent opportunity to do things differently. Accordingly, we must re-focus on re-imagining or reshaping education in Africa, and on reformulating the overarching purpose of education. Even so, it still remains critical to improve mainstream education, to scale up education dramatically, to give all students the opportunity to learn broadly from science to creativity, and to support lifelong learning from kindergarten to beyond university. One key starting point is the need to improve the whole process of 'training the trainers', which in the context of COVID-19 will depend mainly on online education.

The digital transformation of education in Africa is a long-term project requiring sustainable effort, which might be effectively supported by AI. However, it is critical at the outset that AI is seen as just a tool – one that has huge potential, but one that should be at the service of teachers and not the other way round. In fact, AI has to be demystified – it is not magical, nor is it new. Equally, there is no need to panic about AI. In education, AI has two distinct applications. First, to support teaching and learning in order to help massify education. Second, to ensure that all students gain key competencies to enable more young people across the continent to develop the skills needed for the future so that AI enhances human capabilities, and to develop the future AI specialists. This is especially important in Africa to help build resilience, which can have difficulties addressing challenges such as COVID-19 and other shocks.

One possible approach is to create a pan-Africa AI hub. This could be designed to generate knowledge, to include and benefit all, to develop a common African approach involving the public and private sector, to foster a critical mass of AI expertise, to ensure that AI takes into account the specificities of African countries, and to help Africa achieve the Sustainable Development Goals. This would require increased investment in the necessary technological infrastructure, as well as the collaborative sharing of open access resources, and a robust focus on questions of ethics and privacy.

Promoting Equitable Use of AI in Education and support Priority Africa: Key Messages

- This is an excellent opportunity to do things differently: we must re-focus on re-imagining or reshaping education, and on reformulating the purpose of education.
- Improving basic education across the continent remains critical.
- AI should be seen as just a tool – one that has huge potential, but one that should be at the service of teachers and not the other way round.
- AI has to be demystified – it is not magical, nor is it new. Equally, there is no need to panic about AI.
- One possible approach is to create a pan-Africa AI hub designed to develop a common African approach, to foster a critical mass of AI expertise, and to help Africa achieve the UNESCO sustainable development goals.

Empowering women and youth

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While there has been much discussion around the equitable and ethical use of Artificial Intelligence in education to achieve SDG 4, it is essential to focus on empowering women and youth.

Some claim that AI is the new electricity. However, as **H.E. Mr Saaid Amzazi**, Minister of National Education, Vocational Training, Higher Education and Scientific Research, Morocco, acknowledged, there cannot be AI without humans. AI demands new skills, which all citizens need to have in order to prevent them from being excluded. This dependency of AI on humans also underscores the importance of schools, the need for curricula to be developed, and the need for teachers to be appropriately trained.

Nonetheless, it is not yet fully clear how AI will affect education. It is possible that, as **Ms Ethel Agnes Pascua-Valenzuela**, Director, Southeast Asian Ministers of Education Organization Secretariat, Thailand, mentioned, teachers and machines could collaborate in the schools of tomorrow so that students can learn faster and more efficiently.

Ms Dorothy Gordon, Chair, Intergovernmental Council for the Information for All Programme, UNESCO, explained that many current AI tools that have been developed for use in education by international companies pose a range of issues such as cultural biases. To address such biases and reduce cultural erosion, the content needs to be localized, and we need to work towards developing our own solutions. In any case, there is currently little evidence for learning gains from these technologies – something that teachers need to be made aware of. In fact, governments and schools are spending a lot of money without always achieving the expected impact.

H.E. Mr Nasser Al-Aqeeli, Deputy Minister for Research and Innovation, Ministry of Education, Saudi Arabia, indicated that Saudi Arabia has implemented and rigorously tested personalized, adaptive learning tools such that in a few years it is expected to be the norm of Saudi Arabian education.

Other factors, explained **H.E. Mr Vincent Adul**, Communication Technology Expert, Ministry of ICT, Innovation and Youth Affairs, Kenya, include the need to ensure inclusive internet access, reliable and supportive infrastructure using broadband or mobile telephones where appropriate. We also need to undertake human capacity building, for example by training teachers how best to select and

use these tools. All of this requires effective partnerships between governments, schools and the private sector together with a regulatory framework that addresses data privacy and security and the risks of using AI.

The ethics of AI and education need particular attention. **Ms Gabriela Ramos**, Assistant Director-General for Social and Human Sciences, UNESCO, introduced UNESCO's *'Recommendations on the Ethics of AI'*, which raises multiple issues such as diversity, inclusiveness, and human rights. When reflecting on how to deploy such ideas in education, things become very challenging. There is a need to consider how much such technologies should be used in the education cycle. For example, how using an AI tool to maintain children's attention is not necessarily good for their agency. We also need to focus on safety, security, social fairness and non-discrimination, especially for girls. In addition, what is fundamental for the proper application of AI in education is that it should be driven by pedagogy and learning processes, and not by the available technologies. Finally, we also need to recognize that algorithms can go wrong. They are human-made and the reality is that the AI cycle requires a lot of human oversight. The black boxes do not tell us how conclusions are made and they may reproduce existing inequities.

H.E. Dr Ibrahim Bin Saleh Al-Naimi, Undersecretary, Ministry of Education and Higher Education, Qatar, presented the National Artificial Intelligence Strategy of Qatar.[21] He also called for an AI and education forum, for the use of AI in education to address ethical issues such as data privacy, for the key AI competencies that students need to learn to be agreed, for appropriate strategies and policies for international collaboration between governments and for-profit and not-for-profit enterprises to be established, and for the world to embrace openness and transparency.

Empowering Women and Youth: Key Messages

- There cannot be AI without humans, which underscores the importance of schools.
- We need to ensure that AI serves all humanity, in particular all women and young people.
- Algorithms can go wrong. They are human-made and the AI cycle needs a lot of human oversight.
- AI should not be allowed to reproduce stereotypes, ignore social biases, or create new inequities.
- Women should be active participants in AI, more women should be trained in AI, and AI should be designed to ensure gender equality.
- We should support women now, and in the future, to learn skills that machines cannot replicate.
- We need to focus on social fairness and non-discrimination, especially for girls.
- AI might reduce cultural diversity: content needs to be localized to reduce cultural erosion, and countries should work to develop their own solutions.
- There needs to be a reliable and supportive infrastructure, human capacity building, and a regulatory framework that addresses the risks of using AI.
- AI in education should be driven by pedagogy and learning processes, and not by the available technologies.

[21] https://www.motc.gov.qa/sites/default/files/national_ai_strategy_-_english_0.pdf

Implications of the use of AI for curriculum and teaching

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The growing impact of AI in education requires careful consideration of curriculum-related issues and textbooks. This raises multiple questions. How can a curriculum be designed to unleash the potential of AI in education while addressing the challenges? What problems in education might AI solve and what is its purpose? What opportunities does AI provide for students and teachers? What needs to be understood and agreed before AI is implemented in classrooms? How can education adapt to the constant changes in AI? What are the implications of adding AI to the curriculum? What do students and teachers need to understand about how AI works, and what training do they need?

There are many possibilities for how AI might support education. For example, AI might be used to automate routine and administrative tasks, thereby giving teachers more time to spend with their students to provide differentiated and individualized learning and feedback to students, and to provide support outside the classroom such as in the time of COVID-19. AI might also be used diagnose student competencies before offering them personalized learning content and feedback tailored to their needs and localized for the school's context. Alternatively, AI might be a crosscutting tool for the transformation of education in the post-COVID era, or a method for effective data analysis for students and teachers, or a way to improve teaching quality and democratize the teaching process.

In any case, it is critical that humans not lose control to AI. In particular, AI should not replace schools or teachers. Instead, schools need to develop people who control the AI. Indeed, we need to have a general vision for the future, and to think what kind of people and what core competencies we need to cultivate. For example, digital literacy will be achieved by adjusting school curricula – not by adding a new discipline, but rather by embedding AI across all disciplines: ICT, mathematics (modelling, probability, statistics), and ethics, as well as the humanities and arts. This needs to be based on evidence and shared experience, and must be flexible, open, inclusive and continuously evolving – a process that AI might facilitate. In fact, right from the beginning of their education, young people need to be active in their use of AI. The curricula should also involve active pedagogies

in which students are active participants in the learning process and take responsibility for their learning – in other words, learning that makes sense for the learners.

We also need to involve multiple stakeholders to design learning materials and AI-driven interactive textbooks,[22] going beyond the typical reliance on PDFs, and train teachers how to use those pedagogies, materials, and textbooks. Teachers and learners also need to play an active role in the development of AI tools, which has been shown to be possible in countries like the Democratic Republic of the Congo where students are developing algorithms to solve equations. The arrival of AI underscores how important it is to look at best practices from around the world, and to plan for the future. Textbooks are still essential, which is why developments in AI and education need to engage with publishers and parents who are all too often excluded. There is also a need to scale up the training of teachers.

Implications of the Use of AI for Curriculum and Teaching: Key Messages

- AI might be used to automate routine and administrative tasks, to improve teaching quality, and to democratize the teaching process.
- AI might also be used to diagnose student competencies before offering them personalized learning content and feedback localized for the school's context.
- AI should not replace schools or teachers. Instead, schools need to develop people who control the AI.
- The cultivation of the core competencies will be achieved not by adding a new discipline but rather by embedding AI across all disciplines.
- This curricula needs to be based on evidence, must be flexible, open, inclusive and continuously evolving, and should include ICT along with mathematics, statistics and ethics.
- Students should be active participants in the learning process and take responsibility for their learning.
- Multiple stakeholders need to be involved in the design of learning materials, especially AI-driven interactive textbooks, and teachers need to be appropriately trained.

[22] http://www.ibe.unesco.org/sites/default/files/resources/report_ai_forum_parallel_session_1_en_0.pdf

Effective and ethical use of AI in learning and teaching

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With AI beginning to have a revolutionary impact on education, many people have concerns for the prospects of humankind. For example, AI is playing an increasing role in China, and will be fundamental for future education. AI will change the teacher's role in particular. It will take over most knowledge-based teaching and assessment so that teachers are freed from doing 'boring' teaching tasks and can focus on the social aspects of education. AI is already being used to support remote learning in different modes, with classes being *delivered* remotely, classes being *guided* remotely, and classes being *shared* remotely, each of which brings benefits and challenges.

Other ways in which AI might support education include Open Educational Resources (OER) content recommendation systems, detecting student emotions, so-called intelligent tutoring systems, AI-powered teaching assistants, automatic test scoring, automatic forum monitoring and plagiarism detection. One possibility with big potential is the use of AI-human hybrid and other approaches that require fewer resources: for example, the use of WeChat to deliver microlearning. Other possibilities are international competitions like the *'UNESCO King Hamad Bin Isa Al Khalifa Prize for the Use of ICT in Education'*, which is identifying and sharing best practices in the use of AI to ensure the continuity and quality of learning during the COVID-19 education disruption.[23]

Effort also needs to be put into developing appropriate regulations, with the European Union's General Data Protection Regulation providing a useful model, while ensuring that the regulations do not limit the development of AI. Meanwhile, students will need to develop a new range of digital competencies around issues such as information processing, computational thinking and digital learning. AI also has the potential to support this, with AI-powered OER, textbooks, and communities of practice.[24] However, there are many issues that need

[23] https://en.unesco.org/themes/ict-education/ict-education-prize
[24] https://en.unesco.org/news/artificial-intelligence-and-frontier-technologies-open-educational-resources

to be addressed. For example, teachers' professional development needs to be improved, as does governance, accessibility and the trustworthiness of AI. In fact, AI is becoming a catalyst for reforming education itself. For example, it will enable a greater emphasis on project based learning, flexible learning, collaborative learning, and self-regulated learning, thus improving educational quality overall.

The *'AI and the Future of Learning: Expert Panel Report'*[25] recently published by the US-based not-for-profit *'Center for Integrative Research in Computing and Learning Sciences'* makes the following recommendations. AI and education researchers should:

- investigate AI designs for an expanded range of learning scenarios;
- develop AI systems that assist teachers and improve teaching;
- intensify and expand research on AI for assessment of learning;
- accelerate development of human-centred or responsible AI;
- develop stronger policies for ethics and equity;
- inform and involve educational policy-makers and practitioners; and
- strengthen the overall AI and education ecosystem.

Effective and Ethical Use of AI in Learning and Teaching: Key Messages

- AI will change the teacher's role: it will take over most knowledge-based teaching and assessment so that teachers can focus on the social aspects of education.
- AI might support teaching in a range of ways: OER content recommendation, detecting student emotions, so-called intelligent tutoring systems, AI-powered teaching assistants, automatic test scoring, and automatic forum monitoring.
- AI is becoming a catalyst for reforming education itself: it will enable a greater emphasis on project based learning, flexible learning, collaborative learning, and self-regulated learning, thus improving educational quality overall.
- AI is already being used to support remote learning in different modes with classes being delivered remotely, classes being guided remotely, and classes being shared remotely, each of which brings benefits and challenges.
- Students will need to develop a new range of digital competencies around issues such as information processing, computational thinking and digital learning.
- Teachers' professional development needs to be improved, as does governance, accessibility and the trustworthiness of AI.
- AI and education researchers should develop AI systems that assist teachers and improve teaching, accelerate the development of responsible AI, develop stronger policies for ethics and equity, and involve educational policy makers and practitioners.
- The main obstacle to the wide adoption of AI technologies is the lack of robust evidence for its efficacy and its impact on student academic achievements.

[25] https://circls.org/wp-content/uploads/2020/11/CIRCLS-AI-Report-Nov2020.pdf

Follow up actions

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President of Beijing Normal University, People's Republic of China

Ms Stefania Giannini
Assistant Director-General for Education, UNESCO

The *'International Forum on Artificial Intelligence and the Futures of Education'* concluded with keynote speeches by **H.E. Mr Xuejun Tian**, Vice Minister of Education Chairperson of Chinese National Commission for UNESCO, People's Republic of China, **Mr Qi Dong**, President of Beijing Normal University, People's Republic of China, and **Ms Stefania Giannini**, Assistant Director-General for Education, UNESCO. Each of these speakers highlighted key issues that had been introduced by the Forum's participants, and suggested some follow up actions.

H.E. Mr Xuejun Tian began by noting that the 2019 *'International Conference on Artificial Intelligence and Education'* explored the leading role of AI in education and its development in the intelligent age, and adopted the *'Beijing Consensus'*. However, in 2020, the sudden onset of COVID-19 dealt a heavy blow to global education. The intelligent age has, he suggested, come earlier than expected, presenting new challenges calling for our immediate attention.

First, in the age of AI, we need to find new ways of promoting educational development. In 2020, the world witnessed the popularization of unprecedentedly large-scale online education due to COVID-19. Intelligent technologies have been integrated with education and teaching at a faster pace, while traditional class teaching has been replaced by online study that could be carried out at any time in any place. We have come to realize that the constant changes in education delivery models, including the expansion of teaching scenarios, mark the beginning of the intelligent education revolution. Facing the historical trends of AI technology development and educational reforms, we must be forward-looking and innovative in thinking, and get a better understanding of the trends concerning education and talent development. Efforts should also be made to work out the development strategy, standards and paths for intelligent education to realize the integration and advance development of new teaching models.

Second, we need to be more people-centred and promote equity in education in the age of AI. Putting people first is the prerequisite for realizing equitable and quality education. On the one hand, AI development enables us to better cater to the demands of large-scale and individualized education. It helps provide learners with essential abilities, and helps people build values and morals in education and teaching. On the other hand, developing countries and impoverished regions are facing a widening digital divide. To achieve high-quality and inclusive education for all, we must optimize resources allocation, bridge the digital divide, and make education better quality, more efficient and sustainable, thus benefiting all people in a more equal manner.

Third, we should work together to promote common education development in the age of AI. The COVID-19 pandemic has once again proved that all countries have closely intertwined interests and

are dependent on one another. Cooperation is the only right choice for the international community to meet the challenges. We must choose solidarity over disputes and overcome prejudice with rationality. We should respect and help each other through thick and thin, and let UNESCO fully play its role in leading and coordinating intelligent education.

The *'14th Five-Year Plan'* proposal of China, involving future-oriented, all-inclusive, fundamental and targeted measures, was deliberated and adopted. China will pursue wider and deeper educational expansion, and we stand ready to work more closely with UNESCO and various countries to contribute to the international community with a shared future for humankind.

Mr Qi Dong began by highlighting the importance of linking the development and use of AI in education and learning with the research in psychology on children's development and cognitive neuroscience research of children's learning. He highlighted particularly the fundamental question on how we ensure that the combination of Artificial Intelligence and education benefits children's mental health, while improving the quality and efficiency of education and teaching. He continued by mentioning several issues that he believes are worthy of further study.

1. As Artificial Intelligence becomes more pervasive in education, it is becoming increasingly important to ensure that Artificial Intelligence promotes children's healthy development. Children of different ages have distinct features of brain development, which means that Artificial Intelligence has to adopt different ways of facilitating learning for different age groups. In particular, the application of Artificial Intelligence in education must not deprive children of the benefits that come from completing key steps in brain development, but instead should facilitate the completion of those key steps. These effects are worthy of in-depth study.

2. Experts at this meeting have discussed the core needs for literacy of the times. We all know that in this era, everyone needs the ability to learn independently, the ability to innovate, the ability to create, the ability to comprehensively understand, the ability to process emotions, and especially the ability to combine humans and machines. These abilities may not have been cultivated enough in education systems previously, but they are essential for the successful development of intelligence and education.

3. The ethical issues involved in Artificial Intelligence and education. Artificial Intelligence has profoundly affected people's thinking, values, and moral behaviour. Accordingly, a series of ethical issues raised by the application of Artificial Intelligence in education must be carefully considered.

4. Fairness in Artificial Intelligence and education involves the digital divide, and requires us to ensure that Artificial Intelligence does not distinguish between gender, status, or region. The issue of dividing national boundaries in human society is key for ensuring that everyone is able to enjoy more high-quality educational opportunities. I think these issues are also worthy of in-depth study.

Beijing Normal University, as a pioneer in the training of scientific educational research teachers in China, attaches great importance to the research of Artificial Intelligence and education. With the support of the country, we have established the National Engineering Laboratory for Cyberlearning

and Intelligent Technology in cooperation with many institutions and enterprises around the world. Together, we are exploring a series of theoretical and application problems for the successful use of Artificial Intelligence in education. We believe that the successful application of Artificial Intelligence in education will depend on more extensive and in-depth cooperation in the academic, scientific, and educational circles of various countries. We are also willing to provide more support for this cooperation. Let's participate together.

Ms Stefania Giannini noted that the debates during the *'International Forum on Artificial Intelligence and the Futures of Education'* recognized that the pervasive use of Artificial Intelligence will be the distinct feature of the future. Living and working with AI will not be optional. In fact, the future of technology is now; and preparing to live and work safely and effectively with AI is a shared challenge at the global level. Having said this, countries face diverse development challenges and possible futures – the development of AI competencies and the use of AI will need to account for the diversity of local contexts. The Forum debates reaffirmed the shared vision and principles of the *'Beijing Consensus'*, and went on to chart more concrete actions moving forward.

The potential of AI – including automation of low-skill tasks, augmentation of human capacities and amplification of business models – should be used for the benefit of society and for the common good. At the same time, humans should be protected from becoming victims of AI tools. Instead, AI should be a tool at our service towards a sustainable development that is economically and socially just and inclusive. That is our shared goal as expressed in the *'Education 2030 Agenda'*.

The development and implementation of ethical and regulatory frameworks for AI applied in education is therefore absolutely necessary. In fact, keeping AI under control should, by design, enable accountability, transparency and explainability. Another challenge is that AI has the power to transcend borders, making it imperative that regulations are also cross-border. The UNESCO *'Recommendation on the Ethics of AI'* is the international ethical framework that responds to these complex needs.

Humans also need to understand how to control AI. This requires a specific AI mind-set or AI literacy. While we believe in the uniqueness of human intelligence, creativity and ethical reasoning, we should help people understand the theory and practice of Artificial Intelligence. AI literacy includes understanding how AI collects and can manipulate data. It also includes algorithm literacy that comprises knowledge of how algorithms process data and control our behaviours through personalized human-machine communication.

Many countries have already acknowledged the importance of developing AI literacy from an early age. In other words, AI has to be included in school curricula, and must ensure a balance between human- and technology-oriented approaches. All young people need to be empowered to achieve higher levels of AI competence, which can best be achieved by engaging them directly in the design and implementation of AI systems. AI literacy should also be integrated into lifelong learning programmes so that all citizens understand how to interact with AI systems and make informed decisions. To achieve all this, contextual problem-solving methodologies should be adopted to develop AI competencies that can be used to solve real problems in local contexts and to serve sustainable development.

As we have seen, AI tools have demonstrated potential to support the achievement of the SDG 4 commitments and targets - including supporting inclusive education, diagnosing learning problems, augmenting teachers' learning management, and enhancing evidence-based education policy

planning. However, ICT infrastructure, especially connectivity, is the pre-requisite for this potential to be fully leveraged. To address the long-lasting digital divide and ensure that all countries and people benefit from the potential of AI, effective international cooperation is a must. More concretely, international organizations and countries leading in the field of AI must help enhance infrastructure and provide open-source AI tools and resources in the spirit of global solidarity.

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Synthesis Report

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The Global Education 2030 Agenda

UNESCO, as the United Nations' specialized agency for education, is entrusted to lead and coordinate the Education 2030 Agenda, which is part of a global movement to eradicate poverty through 17 Sustainable Development Goals by 2030. Education, essential to achieve all of these goals, has its own dedicated Goal 4, which aims to ***"ensure inclusive and equitable quality education and promote lifelong learning opportunities for all."*** The Education 2030 Framework for Action provides guidance for the implementation of this ambitious goal and commitments.

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Education 2030

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Executive Summary

The 'International Forum on AI and the Futures of Education: Ensuring AI as a Common Good to Transform Education' was co-organized by UNESCO, the Ministry of Education of the People's Republic of China, and the National Commission of the People's Republic of China for UNESCO. Building on the previous 'AI and the Futures of Education' forums, held in 2019 and 2020, this 2021 forum set out to explore the importance and role of digital humanism in AI and education. With people and governments worldwide becoming increasingly aware of both the potential and the challenges of AI and education, the forum engaged participants in dialogue about how AI governance and innovation can be enhanced for the common good. Forum participants included government ministers and other high-level ministry officials from Member States, together with representatives of international organizations, NGOs and academic institutions.

Realizing the potential and addressing the challenges of AI for education

Throughout the forum, participants acknowledged that Artificial intelligence (AI) has the potential to improve certain aspects of education but recognized that it does not provide a complete solution, in particular in areas where digital connectivity remains a challenge. In addition, it was agreed that the use of AI must meet the highest ethical standards, guided by humanistic principles, in order to ensure that AI fulfils the promise of accelerating progress towards the achievement of SDG 4.

Considering the digital as part of the global commons, UNESCO adopts a humanistic approach to technology in education that promotes respect for human dignity and is guided by human rights principles, namely inclusion, equity and gender equality. Recent developments in AI call for a reframing of what it means to be human and its implications for learning. The current context of transformation calls for a redefinition of what we understand by learning to be, learning to know, learning to do and learning to live together.

Teacher training and support are key for the use of AI in education, including for the implementation of AI curricula, as teachers increasingly have to be prepared to work in AI-rich settings. Accordingly, strategies for strengthening the capacities of teachers in the area of AI should be prioritized, while governments should enhance teachers' competencies in understanding and using AI to support teaching and to innovate new pedagogies.

Identifying and addressing the risks

Participants agreed that AI technologies should not be introduced to classrooms by default, but should only be introduced when it is demonstrably beneficial and ethical. Indeed, it is increasingly acknowledged that AI raises significant risks for information security, human rights and privacy – risks that have been amplified by private governance. It is therefore imperative that countries and international agencies together develop international standard-setting instruments

and national regulations to govern the use of AI, particularly for children. Measures to mitigate the ethical threats of AI should include advanced training for government officials and business representatives, as well as for teachers and school representatives.

A key area of concern is the impact of AI and education on gender inequality, which is rooted in existing digital divides yet is more complex, due to biased data and discrimination in algorithms. The school closures due to the COVID-19 pandemic both reaffirmed the importance of digital technologies and exacerbated existing inequalities, particularly the gender gaps in ICT competencies and skills. The gender equality ladder relating to AI and education starts with equitable access to AI, and encouraging women to study AI and participate in the AI industry: the participation and engagement of girls and women in designing and planning AI tools are key for ensuring their voices are heard and their needs are addressed.

Not only can AI data, if biased, and AI algorithms, if badly designed or misused, exacerbate existing discrimination, they can also incentivize violence, hate speech and exclusion. Accordingly, governments should develop appropriate regulations to protect users. However, regulations on their own will not be enough to ensure the safe and ethical use of AI in education or beyond. This requires all citizens to be equipped with basic AI knowledge, skills and values – while recognizing that AI literacy (data literacy and algorithm literacy) is necessary but not sufficient for ensuring that AI serves the common good.

The multiple connections between AI and education

AI and education is not just about the development of adaptive tutoring or other student-facing tools. It is also about collecting appropriate data and analysing it with algorithms to support teaching and learning, decision-making, and the management, assessment and monitoring of education. It is widely recognized that data mining and AI have the potential to improve education management and learning assessment, but this 'datafication' can also bring its own challenges. The risks related to the use of big data and algorithms should not be ignored, while the privacy, security, trust and fundamental rights of students, teachers and families must all be guaranteed.

AI in education also involves teaching about AI, its techniques and technologies, along with its potential impact on humanity. However, according to UNESCO's mapping, only 11 countries currently have government-endorsed K-12 AI curricula (none of which were in Africa), and only around 12% of time in these curricula was allocated to the social and ethical implications of AI, and there are few evaluations on the quality of AI curricula and the effectiveness of the implementation of the curricula. Local curricula are especially important given that countries share similarities but can be radically different from one another. Digital developments, in and around education, need to address and celebrate those differences – for example, algorithms need to be properly contextualized – while ensuring a humanistic approach.

Finally, participants agreed that governments around the world need to learn from one another, and need to develop effective partnerships with industry, academia, the commercial sector and NGOs, and to create a supportive ecosystem that attracts international expertise. They also need to counterbalance the private-sector-driven approach, reinforce the evidence base for quality and effectiveness of AI curricula, and facilitate the development and delivery of high-quality resources and teacher training.

Introduction

UNESCO forums on AI and education: a global platform for knowledge-sharing

Since 2019, UNESCO has been leading global efforts centred on the twin strands of artificial intelligence (AI) and education, aiming to ensure that (i) the introduction of AI into education is for the common good; and (ii) education systems teach the competencies needed for the AI era. These efforts formally began with UNESCO's flagship Mobile Learning Week being dedicated to the theme 'Artificial Intelligence for Sustainable Development' (UNESCO, 2019*a*).

In addition, the first International Conference on AI and Education was co-organized by UNESCO and the Government of the People's Republic of China in Beijing in 2019 (UNESCO, 2019*b*). It was here that the ground-breaking *Beijing Consensus on Artificial Intelligence and Education* was adopted (UNESCO, 2019*c*). To follow up on the implementation of the *Beijing Consensus*, the second international forum was held both online and in person in Beijing in 2020 (UNESCO, 2021*a*). In 2021, the third forum took place, again online and in person in Beijing, under the theme 'Ensuring AI as a Common Good to Transform Education'. Co-organized by the People's Republic of China's Ministry of Education and its National Commission for UNESCO in collaboration with UNESCO, this event set out to explore the importance and role of digital humanism in AI and education. In particular, with people and governments worldwide becoming increasingly aware of both the potential and the challenges of AI and education, the forum engaged participants in dialogue about how AI governance and innovation networks can be enhanced to direct AI to the common good.

Held on 7-8 December 2021, this third forum, which is the focus of this report, involved 73 speakers including ministers, vice-ministers and state secretaries from Cambodia, Côte d'Ivoire, Egypt, Indonesia, Mozambique, Namibia, Pakistan, the People's Republic of China, Portugal, Qatar, the Republic of Korea, Serbia, Slovenia, Sri Lanka, Thailand, Uzbekistan and Viet Nam. Presentations were also made by leading experts from UN agencies, NGOs, the private sector and international organizations. A total of 763 participants from 107 Member States took part. It was also live-streamed on YouTube (in English, French and Chinese) where it was watched by 1,063 international participants, and by the Chinese Ministry of Education's channel, which hosted 7,070 viewers. Together, the three international forums featured more than 200 speeches and presentations and reached more than 8,000 real-time international participants and viewers from more than 150 countries.[1] This series of forums has aimed to become a sustainable platform to promote knowledge-sharing and the achievement of international agreements in the field of AI and education.

1 Videos and speeches from the three international forums can be accessed via https://aiedforum.org.

'The purpose of UNESCO is to contribute to peace and security by promoting collaboration among the nations through education, science and culture…, [and] to realize this purpose, the Organization will collaborate in the work of advancing the mutual knowledge and understanding of peoples, through all means of mass communication, and to that end recommend such international agreements as may be necessary to promote the free flow of ideas by word and image…'

Source: UNESCO (1946)

Towards digital humanism

The forums took place against the backdrop of a global human development crisis, which was observed by the International Commission on the Futures of Education (2021) to include 'widening social and economic inequality, climate change, biodiversity loss, resource use that exceeds planetary boundaries, democratic backsliding and disruptive technological automation'. However, technological innovations can also create opportunities for humans to address these global challenges by changing the trajectory of our societies.

The development of AI is part and parcel of the digital transformation of all facets of our societies – from our daily lives to the world of work and public services including education. Most importantly, the AI-powered digitalization of learning is not only about the transmission of traditional forms of knowledge. Increasingly, it is also about the digitalization of knowledge production and representation, driven by machine learning, increasingly powerful algorithms, and other AI techniques. In general, the rapid growth of human-AI collaboration and the digital transformation of our societies have profound implications for what it means to be human and how people relate to each other and to technology. The traditional conceptions of humanism need to be reframed, and 'digital humanism' needs to be foregrounded to guide our education and development efforts.

In the *Beijing Consensus on AI and Education* and UNESCO's publication *AI and education: Guidance for policy-makers*, which was launched during this forum, the humanistic approach towards the use of AI is clearly articulated: 'the design and use of technology should be in the service of people to enhance human capacity, protect human rights and ensure sustainable development'. More fundamentally, a humanistic approach should frame technological innovation as a digital public good and as part of the global commons that must be freely accessible to all (Miao et al., 2021).

However, the current reality is that AI innovations are not yet adequately directed at the common good of humanity. For example, in a 2021 survey circulated to all Member States by UNESCO on the use of AI to support learning continuity and quality during COVID-19, only five countries reported that they had used AI tools in their education response to the crisis (UNESCO, 2021*b*). While there are increasing numbers of commercial AI tools being developed and implemented across institutions, there are very few AI tools

or practices orientated to the common good of education and humanity. Such tools and practices might include:

- **language- and image-processing technologies that enable inclusive and equitable access** to online learning opportunities for persons with disabilities or from linguistic or cultural minority groups;
- **big data and analytics** to improve the quality of learning, monitor long-term outcomes, and provide early identification of learners at risk of attrition so that timely support can be offered;
- **AI-powered tools to facilitate remote assessments** while empowering teachers and enhancing students' agency; and
- **regulations and strategies** to protect learners' and teachers' human rights, especially their data privacy, and to address other ethical issues such as gender bias in algorithms.

AI and the Futures of Learning

UNESCO released a global report on the futures of education, *Reimagining Our Futures Together: A new social contract for education*, at the 41st session of its General Conference in November 2021 (UNESCO, 2021*c*). In the same year, it launched the *AI and the Futures of Learning* project[2] focused on three complementary strands aiming to:

1 Identifying use cases and analysing trends on leveraging AI to address fundamental needs of learning, through producing a report on AI-enabled futures of learning, guided by *Reimagining Our Futures Together*. This strand of work will also build on UNESCO's *AI and education: Guidance for policy-makers* (Miao et al., 2021).

2 Develop ethical principles for the design, deployment and applications of AI in learning and education, building on the *Recommendation on the Ethics of Artificial Intelligence* adopted by the UNESCO Member States at the 41st session (UNESCO, 2021*d*).

3 Create guiding frameworks on the AI competences needed by all learners to live and learn with AI. A survey of AI curricula in schools has been completed under this strand of work, and the report was presented at the December 2021 forum.

In addition to the enhancement of the global and national governance of AI in education, one of the forum's main aims was to review AI's current use from the perspective of the fundamental need to support the higher-order thinking, creative learning and innovative pedagogy that may be required in the futures of learning.

2 See https://events.unesco.org/event?id=2883602288

Forum structure

The 2021 International Forum on AI and Education was structured around the following sub-themes:

- **Global governance and national policies on AI in education**
  This includes the debate on digital humanism in the context of the futures of education, and the sharing of experiences on how global governance and national policies can be enhanced and synergized to ensure that AI is used for the common good of humanity.
- **Ensuring AI as a common good for achieving SDG 4**
  This sub-theme encompasses knowledge-sharing on best practices and the effective use of trusted AI tools for education, and system-wide principles to guide the next generation of AI innovations to serve teachers and to enable the futures of learning. It also includes examining the definitions of AI literacies and AI curricula frameworks, and the conditions for facilitating their implementation.
- **Mining data to enhance education management and learning assessment**
  This covers the examination of emerging practices of data mining across platforms and multiple data sources to enhance education management, assess lifelong learning outcomes, and diagnose problems in learning systems; an evaluation of the limitations of using data and AI to support learning assessment; and the ethical issues relating to the use of data and AI tools to predict human behaviours, including data privacy and security, and algorithm biases.
- **Promoting gender equality and empowering girls and women with AI competencies**
  This sub-theme involves catalysing AI innovations to advance inclusion, equity and gender equality in education and sustainable development, especially among youth; ensuring that girls and women have equitable access to AI technologies and AI-enabled learning activities; facilitating debate on how to prevent gender discrimination in algorithms and AI tools; and sharing experiences on empowering girls and women with digital skills and AI competencies, as well as increasing their self-efficacy and participation in AI.
- **Promoting the humanistic use of AI in Africa: Build the partnership**
  This last sub-theme includes partnerships and programmes to support the building of the multi-layer and multi-disciplinary basis needed by African countries and other marginalized groups to maximize the potential of AI innovations, and develop the required infrastructure, open-source algorithms and tools, and competencies for key stakeholders.

Following a synopsis of the four opening forum speeches, each of these themes is presented as a synthesis of the ideas, information and views expressed in the sessions. The final section of this report is a synopsis of the follow-up actions recommended by three experts.

Opening speeches

The humanistic vision on the use of AI in education was validated and elaborated by the four opening speeches by **H.E. Mr Huai Jinpeng**, Minister of Education of the People's Republic of China; **Mr Santiago Irazabal Mourão**, President of the 41st session of the General Conference; **Mr Dong Qi**, President of Beijing Normal University (BNU); and **Ms Stefania Giannini**, UNESCO's Assistant Director-General for Education. Each of them spoke about the global challenges of ensuring the inclusive, equitable and ethical use of AI in education.

Mr Huai Jinpeng highlighted the importance of promoting inclusive, equitable and quality education for all as the fundamental prerequisite for using AI in education. In China, the national fiscal expenditure on education has accounted for more than 4 per cent of GDP for 9 consecutive years. In 2020, the gross enrolment rates for pre-school, high school and university students were 85.2 per cent, 91.2 per cent, and 54.4 per cent respectively; and the 9-year compulsory education consolidation rate was 95.2 per cent. As a result, the average length of education of the working population has reached 10.8 years, and is as high as 13.8 years for newer workers. Moreover, the illiteracy rate has dropped to 2.67 per cent.

Mr Jingpeng affirmed three principles for the educational reform and development of China. The first is an insistence on inclusion in education as the foundation of social equity. China adheres to the human-centred development ideology, bases its education policy on equity, and strives to narrow the gaps between urban and rural areas, and among different regions, schools and groups. Mr Jingpeng noted that in 2020 the goal of eliminating poverty in education was broadly achieved, and there was a considerable reduction in the problem of learners dropping out of compulsory education, which has plagued the country for decades. China continues to encourage the sharing of high-quality digital educational resources, and advance toward effectively bridging the digital divide.

MODERATOR

H.E. Mr Xuejun Tian
Vice Minister of Education and Chair of the National Commission of the People's Republic of China for UNESCO, People's Republic of China

SPEAKERS

H.E. Mr Huai Jinpeng
Minister of Education, People's Republic of China

Mr Santiago Irazabal Mourão
President of the 41st session of the General Conference, UNESCO

Mr Dong Qi
President, Beijing Normal University, People's Republic of China

Ms Stefania Giannini
Assistant Director-General for Education, UNESCO

The second principle is to adhere to a vision of high-quality education that the people are satisfied with. China is committed to enabling inclusive access and lifelong learning for all, that is relevant to all learners' needs as well as being open and flexible. Its government also aims to strengthen its technical and vocational education systems, and enhance the development of higher education and the capacities in research and innovation.

The third principle is to persist in reform and innovation. China is reforming assessment mechanisms and teaching practices, and validating the role of digital technology in transforming education. Sustainable programmes are being implemented nationally to accelerate the building of educational neo-infrastructure, promoting the model of 'Internet+Education' and supporting the deployment of technological innovation including AI to catalyse this transformation.

Mr Jinpeng then outlined three key areas that relate to the implementation of the *Recommendation on the Ethics of AI* and some aspects of *Reimagining Our Futures Together: A new social contract for education* (UNESCO, 2021*c*). The first area is China's planned release of a series of policies in response to the development of the new generation of AI, for which it will build an enabling ecosystem.

The second area focuses on the deep integration of AI into education and teaching. This involves initiatives for improving teachers' AI competencies and supporting them to adapt to the use of the internet and AI; innovating pedagogy and approaches to education management; strengthening the production of AI-related curricula; increasing the availability of AI talent; promoting the sustainable development of AI; and integrating AI into all types of education, at all levels, to boost students' digital skills and digital literacy.

The third area is the use of AI to promote lifelong learning for all. This involves constructing an education system in which schools, families and society collaboratively engage in teaching and learning; establishing long-term mechanisms that cater for the entire life course, such as 'banks of digital credits'; using technologies to protect the right to education for disadvantaged groups; exploring the effective integration of multiple learning pathways, methods and processes; and fostering a society that enables learning anytime, anywhere and for anyone.

Mr Jinpeng reminded participants that the world is facing major changes of a magnitude unseen for at least a century. To promote the common good in education, China is willing to work with other countries to advance global cooperation and promote the sharing of experience and wisdom. To this end, he made three recommendations. Firstly, educators and policy-makers should proactively review changes and respond to trends. At present, driven by new theories and technologies such as mobile internet, big data, supercomputing, sensor networks and brain sciences, the advances of AI have accelerated. New features include deep learning, interdisciplinary integration, human-machine collaboration, swarm intelligence and autonomous intelligence. Understanding these latest trends in AI and identifying the breakthroughs and priorities for developing top-level human resources in AI, should be a key mission for education.

Secondly, countries should collaborate through open knowledge sharing, speeding up the pace of digital transformation and intelligent upgrading, supporting international recommendations, and jointly building open, inclusive and resilient education systems. The third and final recommendation is to put safety at the foundation of developments and adopt a stable and long-term approach. The *Recommendation on the Ethics of AI* proposes that, throughout the life cycle of an AI system, measures should be taken to safeguard human beings, the environment and ecosystems (UNESCO, 2021*d*). Education needs to prepare the next generation for the future of human societies. For this reason, more rapid progress is needed to develop and optimize regulations on ethics and safety, and methods for technology deployment and management relating to the use of AI in education. Safety, as the cornerstone of technological transformation, should be solidified to ensure that AI will be used to promote learning and truly benefit human society.

Mr Santiago Irazabal Mourão also highlighted safety, asserting that while AI is likely to transform lives, it triggers many challenges that relate to important ethical issues such as transparency and privacy. The fast development of digital technology can unsettle local and regional standards and values. If misused, algorithms can exacerbate existing discrimination and incentivize violence, hate speech and exclusion. To tackle all these threats, it is essential to consider how AI can be designed for the common good. Education is the most powerful way to put this vision into action. In this regard, UNESCO took an important step to lead the way with the *Beijing Consensus on AI in Education* and the subsequent guidance report for policy-makers (Miao et al., 2021). As there are fewer than 10 years until the UNESCO Agenda 2030 deadline for providing quality education to all, the pace of change must be accelerated.

Next, **Mr Dong Qi** summarized three conclusions stemming from work undertaken in the field of AI in education by 1,000 researchers at BNU. First, cooperation on AI in education should be student-centred. AI needs to support students' learning, well-being and mental health holistically, rather than only focusing on their academic achievement. It could help students develop the lifelong learning and critical thinking skills that are needed in this era. Second, more attention needs to be paid to researching brain development to inform the design of AI in education with better understandings of students' cognitive needs. Third, new technologies such as AI can be harnessed to create systems where students receive individualized support to bolster their mental health, meanwhile generating information that can be used to improve teachers' practice. BNU's researchers will be continuing to work on these three aspects for the next decade and hope that their findings contribute to the 2030 Agenda for Sustainable Development.

Finally, **Ms Stefania Giannini** reminded participants that this forum was preceded by several historical milestones for UNESCO. These include the first International Conference on AI and Education in May 2019, the adoption of the *Recommendation on the Ethics of AI* by 193 Member States in November 2021, and the launch of the report *Reimagining Our Futures Together* (UNESCO,

2021*c*). A human vision runs through these standard-setting documents as a guiding principle on the use of technology. UNESCO's core values are to ensure that when adopting technology, human rights and human dignity are defended; inclusion, equity and gender equality are central; and innovation is considered a common good.

National regulations on data privacy protection must be developed to implement the *Recommendation*. At present, more than one-third of countries do not have any data protection laws. But regulations on their own are insufficient to ensure AI as a common good for education and for humanity. All citizens need to be equipped with some level of AI competency and the knowledge, understanding, skills and values to be 'AI literate', i.e. familiar with what is becoming a basic grammar in the 21st century.

To contribute toward the common good, AI must promote inclusion, equity and gender equality. Algorithms and data interpretation that are exacerbating gender discrimination and prejudice need to be addressed, and the spotlight must shine on supporting the development of AI infrastructure in Africa. Finally, the next generation of the internet, Web 3.0 – or a spectrum of frontier technologies converging under the 'metaverse' – is on the horizon. These innovations have to be steered in the direction of respecting the rights and needs of every learner; making education systems inclusive, innovative and equitable; and giving all learners the mindset, knowledge and humanistic values to shape a more sustainable future.

Global governance and national policies on AI and education

Introduction

It is increasingly acknowledged that the rapid deployment of AI across sectors potentially threatens human rights, exacerbates existing discrimination, and produces new forms of bias and exclusion. The intergovernmental agencies and public bodies of Member States are facing a significant rise in the private governance of AI, imposed by commercial technology providers. Developers, in this landscape, have defined and implemented normative systems in which their digital platforms operate. AI tools usually use algorithms to track users' data, detect patterns of behaviour, and assess users' practices without their full awareness or their explicit or genuinely informed consent. In addition to setting rules, these global corporations are increasingly acting as regulators and dispute-resolution arbiters when conflicts arise. In this way, ordinary people may be denied their human rights, and governments may be unable to represent their citizens. This rise of private governance undermines public accountability for making AI a common good, and leads to a legislative void with respect to the regulation of AI and data across sectors. This state of anomie has further amplified the risks that AI poses to human rights, data privacy, and information security, and increases the potential for the widespread distribution of hate speech and disinformation. Thus, there is a pressing need for global governance as well as national policies covering AI in education.

MODERATOR

Mr Sobhi Tawil
Director, Future of Learning and Innovation, UNESCO

SPEAKERS

H.E. Mr Branko Ružić
First Deputy Prime Minister and Minister of Education, Science and Technological Development, Serbia

H.E. Mr Zhong Denghua
Vice Minister of Education, People's Republic of China

LAUNCH OF THE PUBLICATION:
'AI and education: Guidance for policy-makers'

Mr Fengchun Miao
Chief, Unit for Technology and AI in Education, Future of Learning and Innovation, UNESCO

Mr Wayne Holmes
Institute of Education, University College London

Ms Maïmouna Sissoko Touré
KIX Africa 21 Hub Coordinator, Institute of the Francophonie for Education and Technical and Vocational Education and Training (IFEF)

Ms Mahra Hilal Al Mutaiwei
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The *Recommendation on the Ethics of AI further* interprets the humanistic principles throughout the value chain of the design and application of AI, and across sectors and use cases (UNESCO, 2021*d*). It provides an intergovernmental instrument to support legislation to rebalance this governance landscape. The *Recommendation* still needs to be adopted and implemented through national regulations on AI and data protection. However, as noted in the previous section, less than two-thirds of countries around the world have privacy laws to ensure that citizens' data are under rigorous protections and controls.[3] Beyond such general regulations, policy-makers in the education sector need to deepen their understanding of the unique ethical issues arising from the use of AI in education, such as its reliance on particular pedagogies, and provide practical guidance on regulating the use of learners' data, preventing algorithm discrimination, curbing the use of intrusive AI tools, and promoting human agency in AI-supported learning settings.

The first session on this sub-theme was designed to help UNESCO facilitate the development of international regulations and strengthen national capacities for regulating the use of AI in education. The two speakers were **H.E. Mr Branko Ružić** from Serbia, followed by **H.E. Mr Zhong Denghua** from China.

Mr Ružić said that a report by PricewaterhouseCoopers (2017), *Sizing the Prize*, states that AI will contribute US$15.7 trillion to the global economy by 2030. Serbia is therefore strategically positioning its economy and people to be able to adapt to and harness AI, particularly through education. Serbia has adopted AI curricula and is currently developing more. Its institutes offer seven master's programmes in AI, providing 300 highly trained individuals to the industry every year. There are also training opportunities for traditional industries and small and medium enterprises. A guidance document for AI ethics is expected to be published in 2022, but ethics training is already part of all AI curricula, and is mandatory for all data officers. Education has been a main pillar and focus of development since the national AI strategy was adopted. Nevertheless, more specific applications and revised learning outcomes are being generated, and all existing curricula are continuously monitored for quality and relevance.

Next, **Mr Zhong Denghua** discussed how China's government has undertaken a series of initiatives for building a smart learning environment and exploring appropriate models for it, while also boosting the development of teaching teams and improving education governance capabilities. Specifically, these initiatives include:

3 See https://www.thalesgroup.com/en/markets/digital-identity-and-security/government/magazine/beyond-gdpr-data-protection-around-world

1 Guidelines for the construction of a new six-in-one educational infrastructure – network, platform, resources, campus, application and security – which will be driven by technologies such as AI and big data and built to stimulate digital transformation, intelligent upgrading and innovation.

2 The establishment of 18 'Smart Education Demonstration Zones' to promote the use of AI and other information technologies for updating concepts and exploring new models to foster high-quality learning and improve regional education levels.

3 The launch of pilot projects to develop teachers' AI competencies, in which 56 colleges and universities in 26 regions integrated intelligent technology and deployed teachers with AI competencies.

4 The implementation of the 'Social Experiment on Education under AI' in 10 regions and 19 educational bases, to explore paths toward the AI-enabled modernization of education governance. Furthermore, Guangzhou City and Wuhan City have piloted the integration of AI-related courses into primary and secondary school curricula, while 387 higher vocational colleges and 345 undergraduate colleges and universities have established AI majors.

What has been called the 'age of intelligence' (e.g. Shi, 2021) presents new challenges to the cultivation of students' abilities in innovation, communication, human-computer collaboration, and complex problem-solving, which have become essential. This calls for a transformation of the role of teachers and the approach to school governance. China's Ministry of Education focuses further on the use of AI in education in its forthcoming 'Fourteenth Five-Year Plan for the Digitalization of Education'. Its priorities will centre on 1) deepening the application of AI in education; 2) promoting AI in classrooms; 3) accelerating intelligent education management services; and 4) the ethical and security issues relating to the use of AI in education.

Launch of the publication *AI and education: Guidance for policy-makers*

Currently, *AI and education: Guidance for policy-makers* is available in six languages, and other translations are in progress. It was broadly welcomed by participants for supporting governance, the delivery of inclusive and equitable AI in education, and a critical approach to the impact of AI on real-world learning outcomes. To contribute toward the goal of digital humanism, the publication covers four main areas: AI essentials for policy-makers, key areas and emerging practices, challenges of leveraging AI to achieve SDG 4, and policy reviews and recommendations. A policy structure is proposed wherein AI in education initiatives should cover the following four interlinked aspects and key policy enablers or elements:

1 **Governing and regulating the use of AI in education**
This focuses on ethical issues such as protecting data privacy, preventing algorithm discrimination, regulating intrusive AI-powered tools, promoting human agency in the context of human-machine collaboration, and revealing uncharted ethical concerns.

2 **AI as a common good to deliver unfulfilled promises in education**
This aspect reaffirms that AI should

first be leveraged to address language barriers; meet the needs of learners with disabilities (e.g. sensory impairments, dyslexia and other reading difficulties, and autism spectrum conditions); and monitor learning challenges.

3 **AI as a public good to support pedagogies needed in the future**
This element involves reviewing the current status of the use of AI in education and recommends that it should move from automating low-skill tasks to supporting higher-order tasks and skills for learners.

4 **AI competencies as a cornerstone of the AI era**
Key recommendations under this aspect are presented in the UNESCO global survey on AI curricula for K-12 learners (UNESCO, 2021*b*).

High-level panel on global governance and national policies on AI and education

Panellists debated digital humanism in the context of the futures of education, and shared their experiences on how global governance of AI and national policies can be enhanced and synergized to ensure AI can be used for the common good of humanity and education.

During the COVID-19 pandemic, education suffered greatly in the countries taking part in this high-level panel. In general, technology was beneficial to the delivery of education. However, the lack of infrastructure and equipment in certain areas have caused unequal access. Partly to address these challenges, many countries are beginning to recognize AI as a core area of policy and are preparing to develop and adopt it, especially to support education, which they expect will lead to substantial economic progress. High priorities include training

HIGH-LEVEL PANEL

H.E. Mr Hang Chuon Naron
Minister of Education, Youth and Sports, Cambodia

H.E. Dr. Susil Premajayantha
Minister for Education Reforms, Sri Lanka

H.E. Mr Nguyen Van Phuc
Deputy Minister of Education and Training, Viet Nam

Ms Wajiha Akram
Parliamentary Secretary, Pakistan

H.E. Mr Ahmed Daher
Deputy Minister of Information Technology, Egypt

H.E. Mr João Costa
Deputy Minister of Education, Portugal

Mr Gong Ke
President, World Federation of Engineering Organizations (WFEO), the Executive Director of the Chinese Institute for the New Generation Artificial Intelligence Development Strategies, and the Chairman of the Academic Committee of Nankai University, People's Republic of China

H.E. Mr Jong-chul Jung
Vice Minister of Education, Republic of Korea

H.E. Ms Simona Kustec Lipicer
Minister of Education, Science and Sport, Slovenia

Mr Suphat Champathong
Permanent Secretary, Kingdom of Thailand

the AI engineers of tomorrow, while raising awareness of AI among teachers and students. Many countries are working to bring AI to classrooms in order to provide individualized learning opportunities and tailored teaching approaches, with the collected data being used to monitor how well the SDG goals are being met. However, translating policy into practice is difficult, and while technology can be valuable, it can also increase inequalities.

AI should be viewed as a tool, not a goal, and human intelligence should be prioritized over AI. Therefore, the key challenges include equity, information literacy, ethical implications, critical thinking, time management, and emotional regulation in the AI era.

In concert with UNESCO's *AI and education: Guidance for policy-makers*, some of the panel members revealed plans to further update their existing ethical guidelines. Panel members identified five main issues related to AI governance, namely that it needs to:

- be designed to safeguard human rights and achieve sustainable development;
- aim to foster AI innovation and development;
- be an open, multi-stakeholder system;
- use technology, regulations, education and other tools; and
- engage widely with teachers and students, ensuring their autonomy in teaching and learning.

Panellists also highlighted the importance of teacher training, infrastructure investment for the effective scaling of AI in education, improving curricula to enhance students' higher-order skills, and incorporating human-centred ethical standards.

Global governance and national policies on AI and education
Key takeaways and UNESCO commentary

- AI governance should safeguard human rights and achieve sustainable development; aim to promote AI innovation and development; be an open system for multiple stakeholders; use technology, regulations, and educational tools; and engage widely with teachers and students, ensuring their autonomy in teaching and learning.
- Without global governance and national policies, ordinary people may be denied their human rights, and governments may be unable to represent their citizens.
- AI governance is facing the rapid rise of private governance imposed by commercial technology providers, who are increasingly acting as regulators and dispute-resolution arbiters when conflicts arise. This amplifies risks associated with AI such as discrimination, bias, and the violation of human rights.
- AI tools usually use algorithms to track users' data, detect patterns of behaviour, and assess users' practices without their full awareness or their explicit or genuinely informed consent.
- The *Recommendation on the Ethics of AI* assists legislators in rebalancing the governance landscape. Regulations are needed for safeguarding learners' data, preventing algorithm discrimination, curbing the use of intrusive AI tools, and promoting human agency in AI-supported learning settings.
- UNESCO's *AI and education: Guidance for policy-makers* covers four key areas: the ethical and equitable use of AI in education, AI's potential to deliver unfulfilled promises, how AI can enable learning and digital humanism, and the AI literacy and skills needed for human-AI collaboration.

Ensuring AI as a common good for achieving SDG 4

Speakers noted that AI has been proposed as a key tool for helping Member States achieve SDG 4, ensuring quality education for all. It is true that AI and other innovations, such as blockchain and cloud technologies, are rapidly impacting education. For instance, in China, Cuba, Mexico and Spain AI is already being used to facilitate lifelong learning and equitable quality education for all. This requires a strong infrastructure, which is a key focus around the world, particularly in countries that have many schools in remote, rural areas. It also requires a humanistic perspective, a recognition that education involves affective, behavioural and cognitive dimensions and needs to be firmly grounded in the human and life sciences.

To give a few examples, China is taking a comprehensive approach to AI in the framework of its plan to modernize education by 2035; Spain has recently released a national AI strategy that integrates the public and private sectors; and Cuba, Qatar and Portugal have integrated AI elements into their respective ICT strategies and curricula. Governments' efforts and strategies are complemented by promising initiatives, such as those identified through a call for innovations launched by UNESCO, including:

- Lexplore[4] from the UK, which uses AI and eye-tracking technology to assess reading skills and identify potential barriers to

MODERATOR

Mr Fengchun Miao
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SPEAKERS

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Vice president of China Education Development Strategy Society, Deputy Director of Expert Group on ICT in Education of the Ministry of Education, People's Republic of China

Mr Julio Albalad Gimeno
Director, National Institute of Education Technology and Teacher Development (INTEF), Spain

Mr Jorge Armando Barriguete Meléndez
Secretary General, Mexican National Commission for UNESCO, Mexico

Mr Alain Lamadrid Vallina
Director General of Information, Communication and Informatization, Ministry of Higher Education, Cuba

Mr Liu Pengzhao
Director, Qingdao Municipal Education Bureau, People's Republic of China

4 See https://www.lexplore.com

reading, especially for children who are dyslexic;

- An AI-informed smart learning ecosystem, developed by Hamdan Bin Mohammed Smart University[5] in the United Arab Emirates to offer individualized learning experiences;
- Domoscio from France,[6] which provides tools for adaptive learning and predictive analytics in STEM education and professional training, and offers individualization to students; and
- StorySign,[7] an app designed by the Chinese technology company Huawei to help children who have hearing problems learn to use sign language.

However, in general the pace is still too slow when it comes to developing policies and AI curricula at the national level, and evaluating initiatives in context to check whether they are effective and serve the common good. A greater sense of urgency is required.

The *Beijing Consensus* affirms that human interaction and collaboration between teachers and learners must remain at the core of education, and teachers cannot be displaced by AI systems. It calls on Member States and partners to ensure that teachers' rights and working conditions are protected when adopting AI systems. Regions and countries that have spearheaded the use of AI, including China, the Republic of Korea, and various European nations, have started to review teachers' roles and define the competencies needed in AI-rich

5 See https://www.hbmsu.ac.ae

6 See https://domoscio.com

7 See https://consumer.huawei.com/uk/campaign/storysign

IMPROVED LITERACY IN SCHOOL READING ASSESSMENT AND READING DEVELOPMENT WITH EYE TRACKING AND ARTIFICIAL INTELLIGENCE

Ms Angelica Rådman
Managing Director, Lexplore, Sweden

Ms Souma Alhaj Ali
Director of Excellence and Governance, Hamdan Bin Mohammed Smart University, United Arab Emirates

Mr Benoit Praly
Founder and President of Domoscio, France

UNESCO REPORT ON THE MAPPING OF AI CURRICULA

Mr Fengchun Miao
Chief, Unit for Technology and AI in education, Future of Learning and Innovation, UNESCO

AI CURRICULA FOR SCHOOL STUDENTS IN QATAR

Ms Noha Alomari
Education Specialist, Department of Curriculum and Learning Resources, Ministry of Education and Higher Education, Qatar

AI CURRICULA FOR SCHOOL STUDENTS IN PORTUGAL

Mr Hélder Pais
Head of the Curriculum Development Department, Directorate-General for Education, Ministry of Education, Portugal

LAUNCH OF THE UNESCO-KIDS CODE JEUNESSE PARTNERSHIP ON DATA AND ALGORITHM LITERACY INITIATIVE

Ms Roda Muse
Secretary-General of the Canadian Commission for UNESCO, Canada

Ms Kate Artur
Founder & CEO of Kids Code Jeunesse, Canada

settings. Training programmes for teachers should cover three components: AI literacy; knowledge and skills on domain-specific AI technologies adopted in local education settings; and skills in making pedagogical decisions based on AI-powered learning management systems and data analytics.

It is also necessary to implement training programmes to prepare teachers to work effectively with AI tools, and develop platforms that build on the belief that the quality of teachers is the most important factor in educational success. Countries also need to review evidence-based arguments relating to how AI might influence teaching and learning in the future, and integrate relevant skills into the training accordingly.

Nevertheless, regulations on their own are insufficient to effectively steer AI toward the common good. All citizens – not just those in schools – need to be equipped with some level of competency with regard to AI. This includes the knowledge, understanding, skills and values that might be called AI literacy. Countries also must help citizens develop advanced skills to meet the needs of new jobs created by the adoption of AI and foster local innovations. In fact, it is well-recognized that the most effective way to achieve this is to mainstream AI competency development in curricula for TVET and higher education institutions, as well as schools. However, the 2021 UNESCO report *K-12 AI Curricula*: *A Mapping of Government-Endorsed AI Curricula* found that only 11 countries reported having endorsed K-12 AI curricula (Armenia, Austria, Belgium, China, India, Kuwait, Portugal, Qatar, Republic of Korea, Serbia and United Arab Emirates), while an additional four (Bulgaria, Germany, Jordan and Saudi Arabia) were in the process of doing so (UNESCO, 2022).

These countries are leading the way in AI curricula, adopting a variety of mechanisms for developing AI curricula, including centralized government-led approaches, decentralized government-directed approaches, government-commissioned private provision, and private-sector-driven developments. But more should be done to ensure that approaches are human-centred, and AI is leveraged as a common good to accelerate the achievement of SDG 4. AI curricula are of utmost importance in allowing learners and teachers to acquire the fundamental combination of data literacy (understanding how AI collects, cleans, manipulates and analyses data) and algorithm literacy (understanding how the AI algorithms find patterns and connections in the data, which might be used for human-machine interactions). At the same time, advanced AI skills (including programming, contextual problem-solving, ethical and social issues, and AI techniques and technologies) should also be fostered.

A few recommendations are beginning to emerge. In addition to expediting the development of K-12 AI curricula and strengthening government validation to counterbalance approaches driven by the private sector, countries should pursue 'agnostic approaches' to AI brands and technologies. There is also a need to reinforce the evidence base supporting the quality and effectiveness of these curricula, as the monitoring of existing initiatives is still limited. The risks related to the massive use of data and specific algorithms to exploit

them cannot be ignored, and therefore the privacy, security, trust and fundamental rights of students, teachers and families must be guaranteed. There was also some consensus that teacher training and support remain the most important aspects of AI curriculum implementation, as teachers need to be prepared to work in AI-rich education settings and equipped with data-informed decision-making skills. It is also critical to adopt a human-centred approach and to ensure that teachers are not displaced by AI, as the quality of education remains dependent on the quality of teachers. Finally, at this special historical juncture, there is an urgent need to convene global and regional organizations, governmental agencies, private partners, academic researchers and practitioners to deliberate how AI governance and innovation networks can be mobilized to direct AI toward serving the common good for education and for humanity.

Ensuring AI as a common good for achieving SDG
Key takeaways and UNESCO commentary

- Humanistic approaches are necessary to ensure that AI fulfils the promise to accelerate progress towards the achievement of SDG 4.
- It is important not to lose sight of the key role of teachers in the educational process. Strategies for strengthening the capacities of teachers in the area of AI should be prioritized. Governments should enhance teachers' skills in using AI to deliver learning and innovate new pedagogy.
- Emotional learning and social interaction should not be displaced by AI.
- Basic AI literacy (a combination of data literacy and algorithm literacy) is necessary but not sufficient for directing AI toward the common good.
- According to UNESCO's 2021 mapping, only 11 countries reported having government-endorsed K-12 AI curricula, and none were in Africa. At this stage, there are few evaluations of the impact of existing AI curricula.
- Recommendations arising from the mapping include stronger government validation to counterbalance the private-driven approach, reinforcement of the base of evidence supporting the quality and effectiveness of AI curricula, and resource development and teacher training to facilitate curriculum integration.
- 'If you understand how algorithms work, you will have more power' (Kids Code Jeunesse video).[8]

8 See https://youtu.be/46AcviSU9Rg

Mining data to enhance education management and learning assessment

Speaker noted that data mining and learning analytics are increasingly being used to monitor learning processes, predict failure and attrition, enhance education management, assess lifelong learning outcomes, and diagnose major problems in learning systems. However, evidence for the effectiveness of these applications remains limited, and using data to support learning assessment raises numerous ethical issues relating to privacy and security as well as data and algorithm biases.

Ms Gabriela Ramos, UNESCO's Assistant Director-General for the Social and Human Sciences, noted in her presentation on the *Recommendation on the Ethics of AI* (UNESCO, 2021*d*) that technology should only be introduced in classrooms if it fully respects human rights, inclusion and diversity – yet data analytics can suffer from a lack of transparency and can thus violate some human rights. In fact, most AI and data analytics are not fully transparent: how do such systems make decisions and to what extent are they aligned with core values? Accordingly, the *Recommendation* calls for strict requirements to be met by systems that are used for monitoring and assessing abilities, or predicting learner behaviours. For example, the gathering of data should only be undertaken with the knowledge and consent of the data subjects, no matter their age, while all sensitive information must be fully secured and protected. The *Recommendation*

MODERATOR

Ms Natalia Amelina
Senior National Project Officer in Education, Chief of Unit of Teacher Professional Development and Networking, UNESCO IITE

RECOMMENDATION ON THE ETHICS OF AI

Ms Gabriela Ramos
Assistant Director-General for the Social and Human Sciences, UNESCO

H.E. Mr Rustam Karimjonov
Deputy Minister of the Public Education of Uzbekistan, Uzbekistan

Mr Khalid Abdulla Al-Ali
Assistant Undersecretary for Higher Education, Qatar

Mr Ir Nizam
Director-General for Higher Education, Ministry of Education, Culture, Research and Technology, Indonesia

Mr Zheng Qinghua
Vice President, Professor, Xi'an Jiaotong University, People's Republic of China

Mr Shahbaz Khan
Director of the UNESCO Beijing Office, UNESCO

ViLLE – A COLLABORATIVE LEARNING PLATFORM, WINNER OF THE 2020 UNESCO KING HAMAD BIN ISA AL-KHALIFA PRIZE FOR THE USE OF ICT IN EDUCATION

Mr Mikko-Jussi Laakso
Director, Centre for Learning Analytic, University of Turku, Finland

also identifies a clear need to help students gain the skills that will enable them to cope with these technologies – not only the basic skills of literacy, numeracy and coding, but also critical thinking, social-emotional skills and an understanding of ethics.

Data is also used to train AI tools that can potentially enhance the quality of learning, and it is important to recognize that progress in these applications might be slowed if data protection is especially restrictive. The implementation of a data-driven approach to education management raises complex questions: what data should be collected, where should it be collected from, how is it best analysed, how might it be protected, how can it be used ethically to inform practice, and what will its impact be? Therefore, the effective use of data requires significant investment in the training of all educational stakeholders, from teachers to policy-makers, covering all of these issues.

AI and data can also be used to assess learning and learner engagement, and identify students likely to drop out. For example, ViLLe[9] is a Finnish web platform that provides gamified learning paths in mathematics and computational thinking. Its content is aligned with Finland's curriculum requirements, and it has been shown by its developers to improve student performance by 12 per cent and arithmetic fluency by 11 per cent, over 15 weeks of use. However, as with most initiatives of this type, there is no independent evidence or comparison with other interventions to evaluate learning gains. A second example is OU Analyse.[10]

PREDICTIVE LEARNING ANALYTICS: AN EMPOWERING TOOL AT TEACHERS' FINGERTIPS

Ms Christothea Herodotou
Associate Professor, The Open University, United Kingdom

Ms Toyosi Akerele-Ogunsiji
Social Entrepreneur in Data Science and Artificial Intelligence Education, Nigeria

CONCLUDING REMARKS

Mr Tao Zhan
Director, UNESCO IITE

This is an analytics platform that can predict short-term outcomes (e.g. whether students will submit an assignment on time) and long-term outcomes (e.g. whether they will complete or pass their course), based on data drawn from their interactions with the learning management system. Teachers can use the system to identify which students will benefit from their intervention. The developers have found that the more teachers use the system, the more the outcomes improve, but again the system has not been independently evaluated.

9 See https://en.learninganalytics.fi/ville

10 See https://analyse.kmi.open.ac.uk

Mining data to enhance education management and learning assessment
Key takeaways and UNESCO commentary

- Data mining and learning analytics are increasingly being used to monitor learning processes, predict failure and attrition, enhance education management, assess lifelong learning outcomes, and diagnose major problems in learning systems.
- The *Recommendation on the Ethics of AI* calls for strict requirements to be met by systems that are used for monitoring and assessing abilities, or predicting learner behaviours.
- Evidence for the effectiveness of these applications remains limited, and using data to support learning assessment raises numerous ethical issues, including privacy, security, and algorithm biases.
- The developers of AI in education need to make sure that their systems are transparent, so that the extent to which they are aligned with core values can be understood.
- Technology should only be introduced into classrooms when it is demonstrably beneficial and ethical – if it fully respects human rights, inclusion and diversity.
- Data should only be collected with the clear knowledge and consent of the data subjects, no matter their age.
- All sensitive personal information must be fully secured and protected.
- Data-driven education raises complex questions: what data should be collected, where should it be collected from; how is it best analysed; how might it be protected; how can it be used ethically to inform practice; and what impact will it have?
- All education stakeholders should be given professional training so that they know how to ensure that data mining and learning analytics are both effective and ethical.

Promoting gender equality and empowering girls and women with AI competencies

Speakers noted that the gender gap in digital competencies and skills is becoming wider. In the least developed countries, only 19 per cent of women use the internet compared to 31 per cent of men (ITU, 2021). Women and girls are 25 per cent less likely than men to know how to leverage digital technology for basic purposes, 4 times less likely to know how to program computers, and 13 times less likely to file for a technology patent (EQUALS and UNESCO, 2019). For these reasons and more, the 37th session of UNESCO's General Conference resolved to make gender equity a priority of the Organization, building on the *Priority Gender Equality Action Plan, 2014-2021* (UNESCO, 2019*d*). In 2019, an updated plan was published, entitled *From access to empowerment: UNESCO strategy for gender equality in and through education 2019-2025* (UNESCO, 2019*e*). This action plan proposes a three-step ladder for promoting gender equality, especially relating to technology in education:

Step 1: Eliminate gender inequality in access to digital devices;

Step 2: Empower women and girls with digital skills; and

Step 3: Increase women and girls' self-efficacy in the study of technology and participation in related industries.

MODERATOR

Ms Justine Sass
Chief, Section of Education for Inclusion and Gender Equality, UNESCO

Ms Lindiwe Matlali
Commissioner for the Fourth Industrial revolution, Founder and CEO of Africa Teen Geeks, South Africa

Ms Blerta Cela
Deputy Regional Director, UN Women Regional Office for Europe and Central Asia, Turkey

Ms Nighina Azizov
Programme Analyst, Ending Violence Against Women, UN Women Moldova Country Office, Moldova

Mr Steven Vosloo
UNICEF Digital Policy Specialist, Office of Global Insight and Policy, UNICEF, United States

Ms Shahed Dergham
Teens in AI Ambassador, Syria

Ms Wang Qiong
Professor of Educational Technology, Peking University, People's Republic of China

Ms Corinne Schillizzi
NTT DATA, Italy

Mr Simon Zhang
Chief Brand Officer, StorySign, Huawei, People's Republic of China

In recent years, many countries have focused on improving access to education. However, this can have the unintended consequences of undermining equity, inclusion and overall quality. Children are a particularly vulnerable group who deserve special provisions and attention in the development of AI policies, frameworks and concrete actions. UNICEF recently released the second version of its flagship document *Policy guidance on AI for children*, which includes nine requirements for child-centred AI. In particular, it acknowledges the importance of the participation and engagement of the beneficiaries in designing and planning AI tools in order to guarantee that their voices are heard and their needs are addressed (UNICEF, 2021). This also includes women and girls, and people with disabilities. Everyone is affected by AI, so it is necessary to work with all disadvantaged groups to ensure that no one is left behind.

In addition, AI in the wrong hands can be used to facilitate violence and perpetuate gender stereotypes. Beyond generic training, there should be targeted activities for boys, men and whole communities aimed at reducing digital violence. An example of promising practices directed at preventing violence against women and girls is the Better Futures project in Moldova, which uses a combination of AI, virtual reality and psychological insights to improve behaviours in the long term.

Nonetheless, AI has the potential to assist teachers to become better facilitators in ways that a classic teacher-training programme cannot. For example, the Ms Zora platform[11] in South Africa is a robotics and coding software tool designed to help teachers detect educational problems, improve learner performance, and automate administrative processes by serving as both a teacher's assistant and a learner's personal tutor.

Positive role models in gender equality are key, as is conveyed in the maxim that 'you can't be what you can't see'. It is important to increase access to mentors and role models to help learners understand what AI studies and careers are, and disrupt stereotypes about the role of women in technology. Training programmes should centre on female educators, entrepreneurs and business owners. Such advocacy, visibility and training efforts are necessary also to address the persistent issue of lower perceived self-efficacy among women and girls when dealing with technology. At the same time, partnerships with the private sector should be pursued to generate opportunities for innovation that benefit women and girls, and disadvantaged populations in general. Good examples presented during the forum included:

- The Girl Geek Summit by African Teen Geeks,[12] which exposes young girls to the world of STEM careers, under the tutelage of top-tier local and international female leaders in the industry; and
- Girls in AI Hackathon by TeensInAI,[13] an initiative that aims to inspire and empower girls and young people from under-represented communities across the world to get involved in the field.

11 See https://africateengeeks.co.za/portfolio/mszora

12 See https://africateengeeks.co.za

13 See https://www.teensinai.com

Promoting gender equality and empowering girls and women with AI competencies Key takeaways and UNESCO commentary

- Everyone is affected by AI: it is necessary to work with under-represented groups, especially women and girls, to ensure that no one is left behind.
- It is important to disrupt stereotypes about the role of women in technology, and address the persistent issue of women and girls' lower perceived self-efficacy in this area.
- There should be equitable access to technology and empowerment of girls and women with digital skills and AI competencies, along with their increased representation and greater availability of female mentors in technology industries.
- The end beneficiaries of AI developments, especially those who are often poorly represented (e.g. children, women and girls, persons living with disabilities, and economically disadvantaged groups) should be encouraged and facilitated to participate in the design and development of AI.
- Technology can perpetuate gender stereotypes, and in the wrong hands can even facilitate violence against women and girls. Preventing violence against women depends on establishing training for boys and men.
- Improving gender equity and inclusion is as important as improving access to education.

Promoting the humanistic use of AI in Africa: Build the partnership

At the 37th session of UNESCO's General Conference, at which *Priority Gender Equality* was adopted, another strategy, *Priority Africa at UNESCO: An operational strategy for its implementation, 2014-2021*, was adopted and then launched the following year. It was updated and renewed in 2021 to feature a specific flagship programme on 'Harnessing new and emerging technologies for sustainable development in Africa, including through the implementation of the *Recommendation on the Ethics of Artificial Intelligence*' (UNESCO, 2021*e*). Core objectives of this flagship programme include:

- Improving African countries' capacities to adopt and implement AI;
- Enhancing the capacity of all AI actors in Africa to advance solutions that are ethical, and assess the impact of AI on individuals, society and the environment;
- Enhancing gender equality in the development and use of AI systems;
- Assisting in building inclusive knowledge societies in Africa by mainstreaming open educational resources; and
- Fostering digital skills and competencies, and overcoming the knowledge and digital divides.

MODERATOR

Mr Abdoulaye Ibrahim
Programme Specialist, Priority Africa Coordination Division, UNESCO

INTRODUCTORY REMARKS

Mr Firmin Edouard Matoko
Assistant Director-General for Priority Africa and External Relations, UNESCO

H.E. Mr Albertus Aochamub
Ambassador Extraordinary and Plenipotentiary of Namibia to France, Permanent Delegate, Chairperson of the Africa Group, Namibia

MINISTERIAL STATEMENTS

H.E. Mr Daniel Navigara
Minister of Higher Education, Science and Technology, Mozambique

H.E. Ms Mariatou Koné
Minister of National Education and Literacy, Côte d'Ivoire

Mr Vincent Adul
Communications Technology Expert, Ministry of ICT, Innovation and Youth Affairs, Kenya

Speakers noted that the continuing importance of *Priority Africa* for education was highlighted during the COVID-19 pandemic. Around the world, including in Africa, when schools were closed, digital technologies became a crucial lifeline for accessing distance learning. However, as revealed by the UNESCO-UNICEF-World Bank (2020) joint

surveys, the dearth of broadband connectivity in the least developed countries, including many across the African continent, left one-third to one-half of all learners without access to any distance learning opportunities.

As evidenced by the *Strategy on Technological Innovation in Education (2021-2025)*, adopted at the 211th session of the Executive Board in April 2021, UNESCO is committed to mobilizing resources and providing capacity development to support Member States in planning and managing technology-enabled flexible and crisis-resilient learning systems. The *Strategy* also commits UNESCO to strengthening capacity in the use of big data in learning management systems and stimulating the development of a global data commons. These together will facilitate human rights-based, safe, and ethical sharing of trusted data and algorithms that can help improve teaching and learning (UNESCO, 2021*f*).

However, the use of digital technologies, especially AI, should not be allowed to negatively impact cultural diversity. Each country in Africa is unique, and a digital-humanistic approach requires this wide diversity of cultures to be both catered for and celebrated. In particular, stakeholders need to recognize that the transferability of current algorithms is weak, meaning that algorithms based on data from one group of users cannot be used directly to solve similar problems for groups in other contexts. This causes problems for transferability among nations within the same region but also between developed and developing countries. In other words, algorithms trained on data outside of Africa will inevitably lead to inaccurate predictions, recommendations and decisions. Nonetheless, there is the hope that developing countries who adopt AI later, can learn some lessons from the early use of AI, and direct algorithms to the common good in education.

If African countries are to close the digital and economic divides between them and other countries around the world, they cannot wait for countries from the global north to do what is needed. Instead, they should learn from one other and exchange experiences, knowledge and perspectives. They should also encourage cross-border cooperation and collaboration, in order to build an AI ecosystem across academia, civil society and commerce, and develop effective humanistic AI strategies and frameworks specific to their needs. However, Africa can never close the digital divide alone if they do not have access to the latest technological innovation. Therefore, partnerships are key. For example, international organizations need to help African countries meet the huge challenge of rolling out universal access to the internet across the continent, while AI developers should make their algorithms open and adaptable to the local contexts.

At the same time, African nations need to develop their own local human capacities. This requires a digital transformation that is committed to human rights and is contextualized, to ensure that they do not just consume AI but can guide and inform its effective and ethical development – all of which depends on providing children across Africa with equitable and inclusive access to education. However, as noted earlier, fewer than ten countries among all the UNESCO Member States are implementing governmental AI curricula for school students,

and none of these are from Africa (UNESCO, 2022). AI curricula are not just about the tools that might be used in classrooms. They should also involve value orientation, knowledge and skills to ensure that citizens are literate on key topics such as AI ethics, to train the next generation of AI practitioners. This will generate a critical mass of expertise in Africa.

Privacy and security of data also needs to be carefully considered. Even though cloud-based computing has been promoted as an efficient approach, it has also triggered the issue of 'data sovereignty': how can national institutions maintain the sovereignty of their local data and compliance with national laws and governance structures, when the data are stored in cloud platforms controlled by foreign or private owners? Discussion and experience-sharing are needed to help governments balance cloud-based AI deployment with local ownership of platforms and data.

This part of the forum involved two round table sessions, one on private and institutional partnerships, and the other on academic partnerships.

Round table 1: Partnerships for Africa, involving private and institutional partners

Participants concluded that it is essential to develop an ecosystem that involves international expertise and international synergies but is firmly rooted in Africa and focused on lifelong learning for all. Potentially, Africa has an opportunity to leapfrog the early adopters of AI, as it did with mobile telephones, and can do this in a smart way. For example, at least one project, M-Shule[14]

14 See https://m-shule.com

ROUND TABLE ON PARTNERSHIPS FOR AFRICA: PRIVATE AND INSTITUTIONAL PARTNERSHIPS

Ms Amal El Fallah Seghrouchni
Head of AI movement, The International Center of Artificial Intelligence of Morocco, University Mohammed 6 Polytechnique (UM6P), Morroco

Mr Li Tianchi
CEO, CODEMAO, People's Republic of China

Ms Mona Laroussi
Director, Institut de la Francophonie pour l'éducation et la formation (IFEF), Senegal

Ms Claire Mongeau
Co-Founder & CEO, M-Shule, United Kingdom

ROUND TABLE ON PARTNERSHIPS FOR AFRICA: ACADEMIC PARTNERSHIPS

Ms Rita Bissoonauth
Head, African Union International Center Girls and Womens' Education in Africa (AU/CIEFFA), African Union Commission, Burkina Faso

Ms Ikram Chairi
Mohammed VI Polytechnic University, Morocco

Mr Wang Quan
Vice president, Professor, Xidian University, People's Republic of China

Mr Li Ming
Director, UNESCO International Centre for Higher Education Innovation (ICHEI)

Mr Huang Ronghuai
Professor, Beijing Normal University, People's Republic of China

Ms Helene Charpentier
Senior Project Officer, Association for the Development of Education in Africa (ADEA), Côte d'Ivoire

CONCLUDING REMARKS

Mr Yue Du
Director, Priority Africa Coordination Division, UNESCO

which is based in Kenya, uses AI-powered SMS messages on basic phones to deliver education rather than depending on high-speed broadband access, which is still frequently unavailable, especially in rural areas of Africa. However, it is critical to ensure that AI is not just a new way to deliver traditional education, but that it enables innovation and new approaches to teaching. In short, AI offers the opportunity to develop a new educational paradigm. Finally, governments must recognize that all teachers will need training on how to use AI, data and data traces; and how to apply ethics so that AI enhances gender equality instead of harming it.

Round table 2: Partnerships for Africa, involving academic partners

While Africa faces many challenges, it also has a unique opportunity. More than 2,000 languages are spoken across the continent and there is an abundance of raw talent. In fact, Africa has one of the world's fastest-growing populations, with 60 per cent of its population currently being under 25 years old. To take advantage of the potential within this extraordinary pool of people, governments in Africa need to develop partnerships between academia and civil society. These partnerships should aim to enhance citizens' AI competencies and build their capacities within a human rights context; develop appropriate, localized, and constructive regulations; help young people, especially young women, become the leaders of tomorrow; and identify the deep educational challenges that AI might tackle, not just the sorts of shallow problems that AI developers often tend to focus on. Across all of this, it is essential that countries in Africa adopt UNESCO's humanistic principles that prioritize inclusion, diversity, and human rights. One proposed approach is to deliver hybrid classes, on education, science and the humanities, using AI and educational technologies to support teachers.

Promoting the use of AI in Africa: Build the partnership
Key takeaways and UNESCO commentary

- During the COVID-19 pandemic, the unavailability of broadband connectivity in the least developed countries, including countries across Africa, left almost half of all learners without access to any learning opportunities.
- AI should not be seen as just a new way to deliver traditional education. Instead, AI offers the opportunity to develop a new paradigm.
- AI must not be allowed to negatively impact cultural diversity. Each country in Africa is unique, and a digital-humanistic approach requires this wide diversity to be catered for and celebrated.
- AI algorithms based on data from developed countries cannot be used directly to solve problems in developing countries. However, as later adopters, developing countries can learn lessons from the early adopters, helping them to direct algorithms to the common good in education.
- Countries in Africa need to learn from one other and exchange experiences, knowledge and perspectives, while encouraging cross-border cooperation and collaboration.
- AI curricula should involve value orientation, knowledge and skills to ensure that everybody in Africa becomes AI-literate on key topics such as ethics.
- Governments and international organizations must address concerns around data sovereignty where data are subject to national laws and governance structures yet are stored in cloud platforms controlled by foreign owners.
- Africa can never do this alone; partnerships with international organizations (e.g. UNESCO and the ITU) and private sector providers are key.

Follow-up actions

In closing the forum, three speakers set out what they saw as desired actions, points of consensus, and recommendations that had emerged from the discussions. First, **Mr Firmin Edouard Matoko**, UNESCO Assistant Director-General for Priority Africa and External Relations, said that as a long-term partner of UNESCO, China is committed to supporting the implementation of the Priority Africa Operational Strategy through the China Funds-in-Trust project on Higher Education in Africa for a technical and innovative workforce. Its commitment also contributes to the UNESCO-Huawei project to build technology-enabled crisis-resilient school systems, and the UNESCO Prize for Girls' and Women's Education.

Then **Mr Zhou Zuoyu**, Vice President of BNU, recommended that with the help of AI, education should be redefined. Education helps to transmit knowledge and know-how from one generation to the next, but with AI affecting learning, teaching and assessment, it is now important to focus on protecting humans and promoting humanism to ensure that technology benefits everyone. That, he continued, is a major challenge for everyone. Barriers must be overcome, while full advantage is taken of all the opportunities that new technologies offer, in order to provide a decent way of life for everyone and protect our freedoms. In 2020, BNU adopted a plan to train all of its professors and student teachers, so that they can all contribute effectively to international developments, particularly those enabled by AI. As a world-leading university, BNU endeavours to help peer countries to find innovative methods and teaching environments and progress toward a peaceful world for all.

MODERATOR

Mr QIN Changwei
Secretary General, National Commission of the People's Republic of China for UNESCO, People's Republic of China

SPEAKERS

Mr Firmin Edouard Matoko
Assistant Director-General for Priority Africa and External Relations, UNESCO

Mr Zhou Zuoyu
Vice President, Beijing Normal University, People's Republic of China

H.E. Mr Tian Xuejun
Vice Minister, Ministry of Education, People's Republic of China

Next, **H.E. Mr Tian Xuejun**, China's Vice Minister of Education, reaffirmed his belief that the outcomes of the forum will make positive contributions to the implementation of the 2030 Agenda. As a strategic technology stimulating a new scientific and technological revolution and industrial transformation, AI has shown great potential in shaping the future of learning. The outbreak of COVID-19 has posed severe challenges to the development of global education since 2020. New technologies and hybrid online and offline teaching models have been applied on a large scale, methods and approaches have been continuously innovated, and the

integration of AI technology and education has deepened. These two years of practice have enriched our understanding of the future of education and the innovative application of AI and other emergent technologies in this field.

Three points of consensus achieved during the forum were then summarized. First, **policy guidance needs to be strengthened to enhance the integrated development of AI and education**. Digital technology, represented by AI, will lead to a revolution in education. At this critical historical moment, the initiative should be taken to strengthen policy guidance at the national and global levels for the well-being of humankind. On the one hand, developments in technology and education should be integrated, while on the other hand, safe practices must be developed to guarantee that AI-driven educational reforms benefit all citizens.

Second, **equity and inclusion must be the guiding principles for the development and application of innovative AI technologies in education**. UNESCO's *Recommendation on Open Science* and *Recommendation on the Ethics of AI* should both be implemented in order to vigorously promote the openness of online educational resources and the humanistic deployment of AI (UNESCO, 2021*g*; UNESCO 2021*d*). Theoretical research and practices must be strengthened to prevent discrimination in algorithms and AI tools and make sure that girls and women, people with disabilities, and individuals living in poverty have equitable opportunities to participate in AI-supported learning activities. Moreover, disadvantaged groups should be empowered with AI competencies so that they can fully participate in the era of AI.

Third, **international cooperation should be enhanced to prevent a new digital divide**. The concept of a community with a shared future for humankind must be upheld, adhering to the principles of consultation, contribution and shared benefits. More resources need to be mobilized to build human capacity in developing countries, especially in Africa.

Lastly, the speakers proposed three main recommendations for the way forward. The first was to **capture the 'golden key' of innovation and make AI an important driving force for educational reform**. AI technology changes rapidly and has broad development prospects. It is important to be mindful of its revolutionary impact and constantly deepen and expand theoretical research on the integration of AI with education. Key areas for this include the reform of education governance systems, the upgrading of schools, the iteration of teaching methods, and the improvement of talent cultivation methods through new technologies. It is important to focus on the building of an intelligent system for lifelong learning, thereby providing inexhaustible impetus and lasting support to the development of education.

The second recommendation was that **global and national governance should ensure the ethical and effective application of AI in education**. UNESCO's reports have set out a vision for realizing a peaceful, just and sustainable future through educational transformation and an ethical framework for

AI technologies. Based on the international consensus, it is important to mobilize all the involved parties to properly tackle the risks and challenges of digital fairness, safety, and ethics. Positive interactions should be enhanced: people to people, people to society, and people to technologies, using intelligent technologies to optimize configuration, closing the digital divide, enabling education to truly serve the common good of all people.

The third recommendation was that **an 'overpass' of cooperation needs to be built, making AI a priority topic for international exchanges and collaboration in education**. In response to the major opportunities and complex challenges brought by the new technological revolution, such coordination is the only way forward. UNESCO should spearhead extensive teamwork at the global, regional, North-South, and South-South levels, to actively increase the technical dialogue and shared benefits of quality resources in pursuit of the 2030 Agenda for the development of education worldwide.

Finally, and in summary, it was acknowledged throughout the forum that AI has positive potential for education but does not provide a complete solution to education's global problems. In short, AI brings multiple challenges, and should only be introduced in classrooms when it is demonstrably beneficial. Throughout the forum, participants were also in agreement that, for it to contribute to the common good of all, AI in educational contexts must meet the highest ethical standards, guided by humanistic principles, ensuring human rights, human dignity, inclusion and equity. All of this depends on teachers, government officials and business representatives receiving appropriate training and support to enhance their AI competencies and to make them aware of the possible impacts on humanity so that these might be effectively mitigated. It also depends on international standard-setting instruments and national regulations to govern the use of AI, to counterbalance the private-sector-driven approach, along with locally-sensitive humanistic AI curricula.

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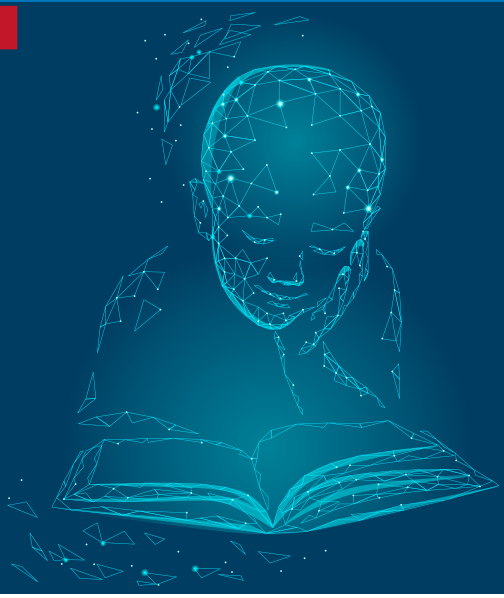
Appendix: Concept note

International Forum on AI and Education

Ensuring AI as a Common Good to Transform Education

7-8 december 2021



#AIED2021

Background

Towards digital humanism: Directing AI innovation towards the common good

As summarized by the International Commission on the Futures of Education,[1] we are in the midst of a global human development crisis: "widening social and economic inequality, climate change, biodiversity loss, resource use that exceeds planetary boundaries, democratic backsliding and disruptive technological automation are the hallmarks of our current historical juncture." Technological innovations bring key opportunities for humans to address these global challenges by transforming our lives and changing the current course of the development of human societies.

1 https://unesdoc.unesco.org/ark:/48223/pf0000375746

The development of Artificial Intelligence (AI) is part and parcel of the digital transformation of all facets of our societies – from our daily lives to the world of work and to public services, including education. Specifically, the AI-powered digitalization of learning is not only about digital transmission of 'traditional' forms of knowledge. It is also increasingly about the digitalization of knowledge production and representation, driven by machine learning and increasingly powerful algorithms. In general, the rapid growth of human-AI collaboration and the digital transformation of our societies have profound implications for what it means to be human and how we relate to each other and to technology. The traditional conceptions of humanism need to be reframed, and a digital humanism is being defined and will guide our education and development efforts.

In the *Beijing Consensus on AI and Education*[2] and UNESCO's recent publication, *AI and education: Guidance for policy-makers*,[3] the humanistic approach towards the use of AI has been clearly articulated: the design and use of technology should be in the service of people to enhance human capacity, protect human rights and ensure sustainable development. More fundamentally, a humanistic approach should frame technological innovation as a digital public good for all and as part of the global commons that must be freely accessible to all.

However, AI innovations are not yet adequately directed at the common good of humanity. In a 2021 survey circulated to all Member States by UNESCO on the use of AI to support the learning continuity and quality during the COVID-19 crisis, only five countries answered positively to the use of AI tools in the education response to COVID-19. Apart from commercially driven AI platforms, there are limited AI tools and AI in education practices orientated to the common good of education and humanity, including: (1) regulations, strategies or tools for protecting learners' and teachers' human rights as well as data privacy; (2) the use of language- and image- processing technologies to enable inclusive and equitable access to online learning opportunities for persons with disabilities and from linguistic and cultural minority groups; (3) the use of data analytics to improve the quality of learning and enable development of interdisciplinary competencies; (4) the use of AI-powered tools to support remote summative assessments and high-stake examinations; and (5) the use of big data to monitor long-term learning outcomes and to provide early warning of education dropouts.

Global governance of the use of AI in education

The rapid deployment of AI across sectors potentially threatens data privacy and human rights, exacerbates existing discrimination, and produces new forms of bias and exclusion. In terms of the governance of AI, the inter-governmental governing bodies and the public governance of Member States are facing the rapid rise of private governance imposed by the commercial AI technology providers. Private AI developers, especially owners of digital platforms, have defined and implemented private normative systems. The algorithms – used by AI tools to track

2 https://unesdoc.unesco.org/ark:/48223/pf0000368303

3 https://unesdoc.unesco.org/ark:/48223/pf0000376709

users' data, recognize behavioural patterns and rate users' practices – are usually implemented without users' full consciousness and explicit consent. In addition to being the rule-setters, the private owners of AI tools are also taking on the roles of regulators of the rules and the resolution bodies when conflicts occur among users and between AI providers and users. The rise of the private governance undermines the public governance that is accountable to make AI a common good.

The Recommendation on the Ethics of Artificial Intelligence adopted by the 41th session of the UNESCO General Conference in November 2021 will therefore provide an instrument to support legislations to rebalance this governance landscape. The Recommendation still needs to be adopted and implemented through national regulations on AI and on data protection. However, up to now, there are still more than one third of countries around the world without any forms of privacy laws for data protection to ensure that citizens' data are offered under rigorous protections and controls.[4] Beyond the general data protection regulations, policy-makers in the education sector need to deepen their understanding of unique ethical issues relating to the use of AI in education, and further provide practical guidance on regulating the use of learners' data, preventing algorithm discrimination, curbing the use of intrusive AI tools, and promoting human agency in AI-supported learning settings. It is therefore imperative for UNESCO to facilitate the adoption of international regulations and strengthen national capacities in regulating the use of AI in education.

AI as a common good for Africa, gender equality and marginalized groups: The basis to build

When schools were closed during the COVID-19 pandemic, digital technologies were the crucial lifeline for accessing distance learning opportunities. During and after the pandemic, digital technologies have become a social necessity to ensure that education as a human right is not disrupted. However, the UNESCO-WB-UNICEF joint surveys revealed that the unavailability of broadband connectivity in the least developed countries left one-third to a half of all learners without access to any distance learning opportunities.

The 211th session of the UNESCO Executive Board adopted UNESCO's Strategy on Technological Innovation in Education (2021 – 2025). The Strategy pays particular attention to UNESCO's global priorities of gender equality and Africa, and places further priority focus on the most vulnerable groups, including persons with disabilities. Through the Strategy, UNESCO is committed to: mobilizing resources and providing capacity development to support Member States in planning and managing technology-enabled flexible and crisis-resilient learning systems; and strengthening capacity in the use of big data in learning management systems and promoting the development of a global data commons to facilitate human rights-based,

4 https://www.thalesgroup.com/en/markets/digital-identity-and-security/government/magazine/beyond-gdprdata-protection-around-world

safe and ethical sharing of trusted data and algorithms that can help improve teaching and learning.

A profound and robust foundation needs to be built if the digital divide is to be closed and the developing countries are to catch up with the AI revolution. This includes:

- **Building AI infrastructure and enhancing country ownership**

This includes promoting universal access to internet connectivity and cloud computing centres with national ownership. Even though cloud-based computing has been promoted to be a more efficient solution, it has also triggered issue on "data sovereignty", which relates to how national institutions can maintain the sovereignty of their data when the data of local groups subject to the national laws and governance structures are stored in cloud platforms controlled by foreign or private owners. With this issue, debates and experience-sharing are needed to balance cloud-based AI deployment and the country ownership of AI platforms and data.

- **Addressing the dilemma between protecting private data and mining data as a public good**

While it is critical to ensure the private ownership of learners' personal data, an extremist approach to data protection will lead to the absence of data available to train AI tools that are potentially a public good to enhance the quality of learning. For example, ViLLE,[5] an AI-powered learning platform developed by the University of Turku of Finland, the Laureate of the 2020 edition of UNESCO Prize for ICT in Education, uses learners' data to monitor learning outcomes and provide early warning for possible dropouts. International knowledge sharing is urgently needed on how countries can possibly address the data dilemma.

- **Designing algorithms relevant to the challenges of local education systems**

The transferability of current algorithms is weak, meaning that algorithms based on data of one group of users cannot be used directly to solve similar problems of groups in different contexts. Developing countries, as late adopters of AI in education, can learn lessons from the early adopters about failing algorithms and direct algorithms at the common good in education. More importantly, developing countries should build locally relevant AI systems using open-source algorithms. One of the examples is M-Shule[6] – or "mobile school" in Swahili from Kenya – one of the first personalized knowledge-building platform developed in Africa to connect learners via SMS to tailored learning, evaluation and activation. For this to happen, international organizations are obliged to promote open-source algorithms.

- **Developing AI competencies and AI literacy**

Regulations on their own are insufficient to ensure AI will be steered for the common good, so all citizens need to be equipped with some level of competency with regard to AI. This

5 https://www.learninganalytics.fi/en/ville

6 https://m-shule.com

includes the knowledge, understanding, skills and value orientation that can be called AI Literacy. Developing countries also need to develop human resources with advanced AI skills to meet the needs of new jobs created by the adoption of AI and to foster local AI innovations. The most effective way is to mainstream AI competencies development in national curriculum for schools, TVET institutions and higher education institutions. However, according to the recent survey conducted by UNESCO on governmental AI curricula for schools, fewer than ten countries among all the Member States are implementing governmental AI curricula for school students, and none of these are from Africa.

- **Preparing teachers to work in AI-rich education settings**

The Beijing Consensus affirms that human interaction and collaboration between teachers and learners must remain at the core of education, and teachers cannot be displaced by AI systems. The Consensus calls on Member States and partners to ensure that teachers' rights and working conditions are protected when adopting AI systems. Leading regions and countries in AI, including China, the Republic of Korea and European countries, have started to review teachers' roles and to define the required competencies in AI-rich education settings. Training programmes have been developed and implemented to prepare teachers to work effectively with AI tools and platforms. Developing countries also need to review evidence-based arguments about how AI might influence teaching and learning in the future, and integrate relevant skills into training programmes.

The Beijing Consensus and the international conferences on AI and education

To support education policy and planning in the era of AI, UNESCO, the Ministry of Education of the People's Republic of China, and the National Commission of the People's Republic of China for UNESCO co-organized the first International Conference on AI and Education (Beijing, May 2019), and the International Forum on AI and the Futures of Education dedicated to a theme on the development of AI competencies (online and in-person meeting in Beijing, December 2020). The Conference in 2019 resulted in the first international consensus on AI and education, the Beijing Consensus.

The Beijing Consensus recommends that UNESCO reinforce its leading role in AI and education across concerned sectors and mobilize the Organization's institutes and networks, and further expand its external networks in the field of AI and education with relevant partners. The Ministry of Education of the People's Republic of China has expressed its commitment to sponsor and co-organize the international event on AI and education annually with UNESCO until an agreement on the termination of the partnership is reached.

The knowledge shared during the Forum of 2020 was published in the *Synthesis report on developing competencies for the AI era*.[7] Building upon the two international events, UNESCO published *AI and Education: Guidance for policy-makers* in April 2021 with an aim to foster AI-ready policy-makers. UNESCO will take the opportunity of this planned International Forum of 2021 to launch the publication in six UN languages. Following up on the outputs of the Forum of 2020, UNESCO launched the project on AI and the Futures of Learning[8] to work on three independent but complementary strands: (1) a report proposing recommendations on AI-enabled futures of learning, (2) a guidance on ethical principles on the use of AI in education, and (3) a guiding framework on AI competencies for school students. In this context, a survey on AI curricula for school education has been completed, and the report will be presented in this planned International Forum of 2021.

Meanwhile, after adopting the Strategy on Technological Innovation in Education in October 2021, UNESCO will adopt Recommendation on the Ethics of Artificial Intelligence and release the global report *Reimagining Our Futures Together: A new social contract for education* at its 41th session of the General Conference in November 2021. At this special historical juncture, there is an urgent need to convene global and regional organizations, governmental agencies, private partners, academic researchers and practitioners to deliberate on how AI governance and AI innovation networks can be enhanced to direct AI at the common good for education and for humanity.

Aim

In response to this need, the Ministry of Education of the People's Republic of China, and the National Commission of the People's Republic of China for UNESCO will co-organize with UNESCO an online edition of the International Forum on Artificial Intelligence and Education on 7 and 8 December 2021 under the theme *Ensuring AI as a Common Good to Transform Education*. The online Forum will deliberate on how AI governance and AI innovation networks can be enhanced to direct AI at the common good for education and for humanity.

Subthemes

The Forum will be structured around the following sub-themes:

1 **Global governance and national policies on AI in education –** Deepen the debate on digital humanism in the context of the futures of education, share experiences on how global governance of AI and national policies can be enhanced and synergized to ensure AI can be used for the common good of humanity and education, and launch UNESCO's report *AI and education: Guidance for policymakers*.

7 https://unesdoc.unesco.org/ark:/48223/pf0000377251

8 https://events.unesco.org/event?id=2883602288

2 **Ensuring AI as a common good for achieving SDG 4 -** Promote proven best practices and effective use of trusted AI tools for education; explore the system-wide principles to guide the nextgeneration of AI innovations to serve teachers and to enable the futures of learning; present the results of the UNESCO surveys on governmental and non-governmental AI curricula for school education, share knowledge on defining AI literacies and frameworks on AI curriculum as well as on preparing teachers to work in AI-rich settings.

3 **Mining data to enhance education management and learning assessment -** Examines the emerging practices of mining data across platforms or multiple data sources to enhance education management and public service, assess lifelong learning outcomes, and diagnose the major problems of learning systems; assess the limitation in using data and AI to support learning assessment and ethical issues relating to the use of data and AI tools to predict human behaviours including data privacy and security, and algorithm biases.

4 **Directing AI innovations at inclusion, equity and gender equality in education –** Catalyze AI innovations to advance inclusion, equity and gender equality in education as well as sustainable development especially among youth; promote gender equality to ensure that girls and women have equitable access to AI technologies and AI-enabled learning activities; facilitate debate on how to prevent gender discrimination in algorithms and AI tools; share experiences on empowering girls and women with digital skills and AI competencies, and increasing their self-efficacy and participation in AI areas.

5 **Promoting the use of AI in Africa: Build the partnership** – Focus on partnerships and well-resourced programmes to support the building of the multi-layer and multi-disciplinary basis needed by African countries and other marginalized groups to maximize the potential of AI innovations including building AI infrastructure, promoting open-source AI algorithms and AI tools, and developing AI competencies for key stakeholders.

Target Participants

The participants will include Ministers of Education and/or ICT, senior policy-makers, experts from international organizations, representatives of private sector partners and civil society organizations, prominent academic researchers, and managers of selected AI in education projects.

Co-organizers

The Forum is co-organized by:

- United Nations Educational, Scientific and Cultural Organization
- Ministry of Education of the People's Republic of China

- National Commission of the People's Republic of China for UNESCO

The following institutes are providing support in hosting the Forum:

- Beijing Normal University
- UNESCO Institute for Information Technologies in Education

Financial support has been provided by:

- National Commission of the People's Republic of China for UNESCO

Working Languages

Interpretation services will be provided in English, French and Chinese.

Provisional Programme Structure

(CET Time, Paris Time)

<table>
<tr><th colspan="2">Day 1 (7 December 2021)</th><th colspan="2">Day 2 (8 December 2021)</th></tr>
<tr><td rowspan="3">09:30-11:30</td><td rowspan="3">Opening Session
and
Session 1:
High-level panel on global governance and national policies on AI in education
Sign in</td><td>09:00-10:30</td><td>Session 3:
High-level panel on mining data to enhance education management and learning assessment
Sign in</td></tr>
<tr><td>10:30-11:00</td><td>Break</td></tr>
<tr><td>11:00-12:30</td><td>Session 4:
Promoting gender equality and empowering girls and women with AI competencies
Sign in</td></tr>
<tr><td>11:30-12:00</td><td>Break</td><td>12:30-13:00</td><td>Break</td></tr>
<tr><td rowspan="2">12:00-14:00</td><td rowspan="2">Session 2:
Ensuring AI as a common good for achieving SDG 4
Sign in</td><td>13:00-14:30</td><td>Session 5:
Promoting the use of AI in Africa: Build the partnership
Sign in</td></tr>
<tr><td>14:30-15:00</td><td>Closing Session
Sign in</td></tr>
</table>

Session 1 - High-level panel on global governance and national policies on AI in education is scheduled back to back with the Opening Session, and presents speeches of high-level speakers of international organizations and ministers on how global governance of AI can be enhanced by the cross-border adoption and implementation of international regulations, as well as on how national strategies on AI and education are being developed to promote the use of AI for the common good of education. During the high-level panel, the latest UNESCO publication, *AI and education: Guidance for policy-makers*, will be launched in the six UN languages.

Session 2 - Ensuring AI as a common good for achieving SDG 4 presents the report of the UNESCO surveys on governmental and non-governmental AI curricula for school education, and reviews how AI literacies and advanced AI competencies are being defined and developed. It shares recommendations on how governmental agencies and partners should collaborate to develop competencies needed by human-AI collaboration, and demonstrates innovative examples on AI competencies development. During the session, a partnership for developing algorithm and data literacy will be announced.

Session 3 - High-level panel on mining data to enhance education management and learning assessment examines the emerging practices of mining data across platforms or multiple data sources to enhance education management, assess lifelong learning outcomes, and diagnose the major problems of learning systems. Specific focus will be given to the use of learning analytics to monitor learning processes and to predict learning failure in order to alert education administrators and policy-makers to dropouts. The session will examine the limitation in using data and AI to support learning assessment and ethical issues relating to the use of data and AI tools to assess and predict human behaviours including data privacy and security, and algorithm biases.

Session 4 - Promoting gender equality and empowering girls and women with AI competencies shares programmes on promoting gender equality to ensure that girls and women have equitable access to AI technologies and AI-enabled learning activities. The session aims to present gender-transformative interventions to empower girls and women with digital skills and AI competencies, and increase their self-efficacy and participation in AI areas. It also facilitates the sharing of knowledge on how to prevent gender discrimination in algorithms and AI tools.

Session 5 - Promoting the use of AI in Africa: Build the partnership focuses on building and promoting partnerships and well-resourced programmes with a vision to build a multi-layer and multi-disciplinary basis needed by African countries and other marginalized groups to maximize the potential of AI innovations. The session aims to strengthen operational partnerships for building AI infrastructure with a special focus on promoting open-source AI algorithms and AI tools as well as the development of AI competencies for key stakeholders. The session will also serve as a follow-up action to other initiatives set out within the framework of UNESCO's Global Priority Africa, in particular the 2018 Benguerir Outcome Statement

adopted at UNESCO's First Forum on Artificial Intelligence in Africa. The latest progress on the organization of regional forums on AI in Africa will be shared.

Session 5 will is followed immediately by the **Closing Session.**

Technical specifications

The event uses Zoom applications to support the live sessions, and uses an online conferencing website to support the registration, the update of live sessions and networking among participants. Live streaming platforms will be used to expand real-time participation.

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International Forum on AI and Education

Ensuring AI as a Common Good to Transform Education

Synthesis Report

The **third International Forum on Artificial Intelligence and Education**, held in 2021, explored the theme 'Ensuring AI as a Common Good to Transform Education'. This publication is a synthesis of the key discussions, focusing on the role in AI and education of digital humanism, and on how AI governance and AI innovation networks can be enhanced to direct AI to the common good for education and humanity.

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18 - 20 August 2022



Synthesis Report

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一百二十周年校庆
120th Anniversary of Beijing Normal University
1902 - 2022

Beijing Normal University

Beijing Normal University (BNU) grew out of the Education Department of Imperial University of Peking established in 1902, which initiated teacher training in China's higher education. After the development for over a century, BNU has become a comprehensive and research-intensive university with its main characteristics of basic disciplines in sciences and humanities, teacher education and educational science.

UNESCO IITE

The UNESCO Institute for Information Technologies in Education was established as an integral part of UNESCO by the General Conference of UNESCO at its 29th session (November 1997) and is located in Moscow, Russian Federation. IITE is the only UNESCO category 1 Institute that holds a global mandate for ICT in education.

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Coordinator: ZENG Haijun, MIAO Miao, QIN Zhaohong

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Be in awe of education, for it shapes the soul of human,

Be cautious to technologies, for its adoption has to be effective,

Be entangled with Smart, for the uncertainty tends to be increasing,

Be serious to academies, for the true research needs evidence.

--- HUANG Ronghuai March 20th, 2017

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University of La Rioja in Spain, Federal University of Alagoas in Brazil, Hangzhou Normal University in China, State Key Laboratory of Virtual Reality Technology and Systems in Beihang University, Educational Informatization Strategy Research Base (Beijing, Central China, Northwest) of Ministry of Education of P.R.C, the Open University of China, Beijing Design Society, Beijing Institute of Education, Intelligent Education Research Center of Shenzhen University, and local venues held at Wenzhou, Bengbu, and Wuhou district in Chengdu, etc.

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北京師範大學
BEIJING NORMAL UNIVERSITY

Co-organizer

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Institute for Information Technologies in Education

Hosts

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中国基础教育质量监测协同创新中心
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CIT National Engineering Research Center of Cyberlearning and Intelligent Technology

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Executive Summary

To promote the digital transformation and intelligent upgrade in education and strengthen international communication, BNU convened the Global Smart Education Conference 2022 (GSE2022) in conjunction with international organizations, universities and research institutions on 18th-20th August 2022. The theme of this conference is “Intelligent Technology and Digital Transformation in Education”. GSE2022 is organized by Beijing Normal University, co-organized by UNESCO Institute for Information Technologies in Education, and jointly hosted by Smart Learning Institute of Beijing Normal University, China Institute of Education and Social Development, Collaborative Innovation Centre of Assessment for Basic Education Quality, National Engineering Research Center of Cyberlearning and Intelligent Technology, Educational Informatization Strategy Research Base of the Ministry of Education (Beijing), etc.

GSE2022 featured by 12 thematic forums. They are Opening Ceremony & Forum on Digital Transformation for Smart Education, Forum on Teacher Education in Metaverse World, Forum on Promoting Digital Literacy in Smart Learning Environment, Forum on the New Ecology of Regional Smart Education, Teacher Forum on Technology Empowered Teaching Innovation, Student Forum on Learning Crisis and Futures of Education, The 6th International Conference on Smart Learning Environments, Forum on Smart Village and Transformation of Rural Education, Forum on AI-driven Open Education, Forum on Digital Governance of Education, Forum on Reform of School Education in the Intelligent Era, Forum on Leveraging Intelligent Technology for Education Innovation & Closing Ceremony.

Forum participants included government ministers, representatives of international organizations, and academic institutions. Experts and scholars from the fields of education and technology were also invited to discuss new theories, emerging technologies, latest achievements and trends in smart education, share relevant cases, build platforms for communication and establish alliances for cooperation. Altogether more than 200 domestic and overseas speakers attended our conference, including 15 student speakers. GSE2022 provided five participant modes, namely, live streaming, main venue, local venues, ZOOM meeting, and metaverse exhibition. The livestreaming of the GSE2022 was watched by more than 8,000,000 viewers.

GSE2022 released the outcome of a joint project of *Rethinking and Redesigning National Smart Education Strategy, a Report on the Construction Progress of Demonstration Zone of Smart Education and best practices of smart education, and an International Report of Supportive Environment on Artificial Intelligence Courses in K-12*. The Initiative for Global Smart Education Network (GSENet) and the Academic Network for Education of China-CEEC Higher Education Institutions Consortium (CCHEIC) were also launched on the conference.

Our conference seized the opportunities brought by the current era, focusing on “five concerns”:

- the fields of technology and education are both actively influencing each other, and showing a development trend of systematic integration;

- in the face of uncertain crises, the Futures of Education needs a new social contract for transformation, and young students shall take concrete actions to promote the global development initiative;
- we shall not only make full use of intelligent technology to empower teacher professional development but also examine the challenges of teacher education and teacher development brought by the intelligent era in an objective and rational manner;
- building the new ecology of smart education includes but is not limited to the planning of digital strategy and system, the construction of new infrastructure, technology-supported pedagogic transformation, and technology-empowered innovative evaluation; and
- rural revitalization is facing a major issue in all countries. We shall pay equal importance to construct the smart village and the smart city to transform rural education effectively.

Finally, we are pleased to announce that the Global Smart Education Conference 2023 will be held on August 18th - 20th, 2023. We are already looking forward to next year together, and having the opportunity to connect with our friends again.



Group photo of speakers at Opening Ceremony at BNU

Introduction

From 2016 to 2019, Beijing Normal University, jointly with other institutions have held four consecutive US-China Smart Education Conference (UCSEC) to explore the development trend of future educational technologies and released relevant research reports that have exerted great influences.

In order to further understand the latest achievements and development trends in smart education, grasp the influences of AI on the futures of education, discuss the factors, features, plans and potential problems in IT-driven educational development, Beijing Normal University, with the approval from the Ministry of Education, collaborated with international organizations and other Higher Education Institutions to hold the Global Smart Education Conference 2020 on August 20-22, 2020 with the theme of *AI and Futures of Education.*

With a focus on identifying the promise of futures of education, the Global Smart Education Conference 2021 was held on August 18-20, 2021 with the theme of *Smart Learning and Futures of Education*. The plural form of "Futures" emphasized multiple dimensions to the future and appealed to reimagine how education and knowledge shall shape the future of humanity in a context of complexity and uncertainty.

Held on 18-20 August 2022, this Global Smart Education Conference 2022, which is the focus of this report, involved more than 200 speakers from 48 countries, including ministers, vice-minister and experts from international organizations, academic institutions, and private sectors. The conference included 12 thematic forums and took a hybrid mode with online and onsite sessions. International research outcomes and related sets of cases were released during the event. Technologies including VR/AR were applied to build a metaverse venue to improve audiences' experience of communication and interaction and also to display our innovative solutions for digital education. The conference also live-streamed and watched by 8 million views. This series of forums has aimed to become a sustainable platform to promote knowledge sharing and the achievement of international agreements in the field of smart education.

Intelligent Technology Empowerment for Smart Education

With the evolution of global digitization, the exploration and practice of technology-transformed education is also expanding from single technology empowerment to multi-dimensions of social transformation, technology empowerment, and educational reform. Technology empowerment is the core value of integrating intelligent technology into education, and student growth, teacher development and environmental upgrading are the core areas of technology-empowered education.

The strategic significance of digital transformation in education is in the same vein with digital China and the digital economy. It means that education shall actively

- adapt to the trend of a new round of technological revolution;
- promote the digital transformation of all elements, all services, all fields and all processes;
- rethink the standards of talent training from the perspective of a smart society;

- optimize and upgrade the digital learning environment;
- change the teaching and evaluation model;
- promote system and mechanism innovation;
- establish an inclusive, fair, green, high-quality and sustainable smart education system that adapts to the intelligent era; and
- improve lifelong learning system that people can learn at any time and anywhere. Finally, it is also necessary to pay attention to regional differences and urban-rural differences, fully consider the digital divide in the application of intelligent technology, establish an inclusive and fair culture, and consider the development of each individual student.

Capacity Building and Teacher Professional Development under Digital Transformation

The fundamental task of education digital transformation strategy is to optimize, innovate and reconstruct the values of organizations and institutions. From the perspective of education system reform, it is the digital transformation of all elements, processes, businesses and fields of education, and the building of a smart education development ecology. The core path is digital capacity building, which aims to improve the digital literacy and skills of students, teachers, administrators and parents. The key drivers of education digital transformation strategy are data and resources. The main aspect of education reform is the classroom; classroom teaching is the core of digital transformation; and teaching content is the foundation of digital applications and services. At present, the application technology and products such as the multimodal data analysis are still immature, and based on the traditional elements, there are still bottlenecks and obstacles in the digitalization of teaching. However, with the help of traditional paper textbooks and exercise books, digital teaching materials, and intelligent teaching tools and equipment, there will be feasible path for solving the current problem, including exploring new teaching modes, improving classroom teaching efficiency, reducing the burden on teachers and students, and cultivating students' new abilities.

Smart Learning Environment for Digital Transformation

An intelligent learning environment is the basis for realizing the transformation of learning and teaching methods and supporting the development of smart education. At present, both traditional classrooms and multimedia classrooms are single teaching locations or teaching scenes, so the teaching process in different environments is fragmented, the teaching interaction is insufficient, and the learning status is difficult to track. For the digital transformation of the school environment, there are several important focuses, including

- promoting the application of new-generation information technologies;
- optimizing and upgrading basic facilities, hardware equipment, network conditions, intelligent tools, and learning platforms;
- continuing to build smart campuses, smart classrooms, and smart living places;
- creating smart learning space with three kinds of deep integration, namely, time, space and teaching, offline and online, virtuality and reality;
- promoting context-based, experiential, and immersive teaching;
- breaking through the data and information barriers between schools, families and society; and

- using learning analysis, educational data mining and other means to improve the matching of teaching service supply and learning needs.

Educational evaluation is related to the direction of education development and affects the way of teaching and learning to a large extent. Deepening the reform of education evaluation in the new era requires the innovation of evaluation tools as well as the utilization of modern information technologies such as artificial intelligence and big data, which aims to explore new ways for carrying out vertical evaluation of students' whole learning process and horizontal evaluation of all elements of moral, intellectual, physical, aesthetic, and labour.

The trend of the digital reform of education evaluation is to apply big data perception, interconnection, storage, computing and analysis technologies, build cross-regional and cross-scene intelligent assessment system platform and tools, optimize and combine data-based evaluation methods, promote the close integration of the evaluation process with the learning process, complete the evaluation during the learning process, and support the organic combination of large-scale education and personalized training.

Public Service System and Digital Governance of Education

Insufficient capacity for supporting services is the main bottleneck of education informatization in rural areas. Only by improving the national and regional education public service capacity can we effectively promote the digital transformation of education. At the national level, the focuses are on

- strengthening the national smart education public service platform, large resource system and educational brain construction;
- formulating a system for the confirmation, opening, connection and protection of educational big data; and
- promoting data integration between platforms at all levels.

At the regional level, the focuses are on

- integrating and optimizing digital educational organizations;
- making full use of the national smart education public service platform to continuously expand the coverage and application of targeted objects;
- optimizing the supply channels of digital educational resources inside and outside the school;
- meeting diversified educational needs;
- strengthening the governance of digital learning products and services for young people; and
- forming new strategies and capabilities for education digital governance.

Forum Structure

The Global Smart Education Conference 2022 was structured around the following 12 thematic forums:

- **Digital Transformation for Smart Education**

This forum highlighted the issues on the connotation, international experience and challenges, and implementation path of digital transformation in education. The results of Rethinking and Redesigning National Smart Education Strategy were released, and the Initiative for Global Smart Education Network (GSENet) was launched.

- **Teacher Education in Metaverse World**

This forum conducted in-depth discussions on topics including “the metaverse and its educational potential”, “the application scenarios of the metaverse in education”, “metaverse-empowered teacher education”, and “the AI-driven teacher development”. The discussion provided new directions toward designing innovative metaverse scenarios and technology-empowered teacher professional development. It also suggested new ideas for seeking the development path of high-quality education, reshaping the relationship between main educational stakeholders, and solving educational fairness and other issues.

- **Digital Literacy in Smart Learning Environment**

This forum highlighted the issues on the metaverse and its educational potential, application scenarios of the metaverse in education, the metaverse-empowered teacher education, and AI-driven teacher development. *The Academic Network for Education of China-CEEC Higher Education Institutions Consortium* was released.

- **The 6th International Conference on Smart Learning Environments**

The International Conference on Smart Learning Environments 2022 will be jointly held on August 18-20, 2022 at the Hangzhou Normal University, The International University of La Rioja, and Near East University. The theme is “Intelligent Technology Enhanced Smart Learning”. It aims to bring together researchers, practitioners, and policy makers to discuss issues related to the optimization of learning environments to enhance learning. The focus is on the interplay of pedagogy, technology and their fusion towards the advancement of smart learning environments.

- **New Ecology of Regional Smart Education**

This forum highlighted the issues on the digital transformation in education and the development of regional smart education, the construction of smart campuses and new ecology of education, the construction of regional smart education empowered by intelligent technologies, and the innovative management and application of smart education.

- **Student Forum on Learning Crisis and Futures of Education**

This forum highlighted the issues on solving the learning crisis through transforming learning environments and developing learning methods, developing competencies for sustainable development among rural students, and integrating resources to achieve inclusive education.

- **Teacher Forum on Technology Empowered Teaching Innovation**

This forum highlighted the issues on technology-empowered teachers' professional development, application, and exploration of technology in teaching, technology-supported smart teaching and research, empirical research on teaching intervention, etc.

- **Smart Village and Transformation of Rural Education**

This forum highlighted the issues on the opportunities and challenges brought by the digital transformation in education to rural education and rural transformation; the development status, successful cases and experiences of smart village and rural (education) transformation in various countries and regions; and how to plan, implement, and assess the sustainability of smart village and rural development.

- **AI-driven Open Education**

This forum highlighted the issues on how can open education and artificial intelligence promote more inclusive and equitable education, how to improve the teaching effect in open education through artificial intelligence, the advantages and limitations of AI in open education, and whether the integration of AI strengthen or reduce bias in open education.

- **Digital Governance of Education**

This forum highlighted the issues on cutting-edge digital technology, rural education governance, the application and governance of “Internet + education”, and digital transformation in regional education, aiming to explore new data-based educational governance models.

- **Reform of School Education in the Intelligent Era**

This forum conducted in-depth discussions on salient topics, including how intelligent technology empowers the high-quality development of basic education, the future prospects of school education in the intelligent era, students' mental health assessment and inquiry-based learning in the intelligent era, and the path and practice of digital transformation in primary and secondary schools.

- **Leveraging Intelligent Technology for Education Innovation**

This forum highlighted issues on the connotation, application scenarios, scientific problems, and key technologies for leveraging intelligent technology for education innovation. The exploration and practice of how to leverage intelligent technology for education transformation is seen from four dimensions, namely, social transformation, technology empowerment, education reform and reform in an orderly manner.

Opening Speeches

Speakers at the opening ceremony spoke about the implementation of strategic action of digital transformation in education, and the promotion of sustainable development of smart education. They are **Mr LEI Chaozi**, the Director of the Department of Science, Technology and Informatization, on behalf of **H.E. Mr ZHONG Denghua**, the Vice Minister of the Ministry of Education of P.R.C; **Mr MA Jun**, the President of Beijing Normal University; **Professor ZHAO Qinping**, the Academician of the Chinese Academy of Engineering; **H.E. Mr Branko Ruzic**, the First Deputy Prime Minister and Minister of Education, Science and Technological Development in Serbia; **HRH Princess Adejoke Orelope-Adefulire**, the Senior Special Assistant to the President on SDGs in Nigeria; **H.E. Mr Azat Athalye**, the Deputy Minister of Education in Turkmenistan; **Professor ZHAN Tao**, Director of UNESCO IITE.

On behalf of **H.E. Mr ZHONG Denghua**, who is the Vice Minister of the Ministry of Education of P.R.C, **Mr LEI Chaozi**, the Director of the Department of Science, Technology and Informatization, addressed the conference. He emphasized the Chinese government has always given priority to education during economic and social development. The government also adheres to fair, inclusive, and high-quality development, reform and innovation. At present, the new form of education promoted by intelligent technology puts forward new and higher requirements for educational reform. The Chinese government has attached great importance to the impact of new technologies in education, actively promoted the digital transformation and intelligent upgrading in education, built a Smart Education Platform in China, and expanded the coverage of high-quality education resources. Moreover, it strengthened the application of educational big data and

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Vice Minister, Ministry of Education, P.R.C

Mr MA Jun
President, Beijing Normal University, China

Prof. ZHAO Qinping
Academician of Chinese Academy of Engineering

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HRH. Princess Adejoke Orelope-Adefulire
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H.E. Mr Azat Atayew
Vice Minister of Education, Turkmenistan

Prof. ZHAN Tao
Director, UNESCO IITE

Prof. HUANG Ronghuai
Co-dean, Smart Learning Institute of BNU

actively created a digital education governance system with Chinese characteristics. Overall, it accelerated the improvement of the infrastructure for information technology in education, and built a high-quality education support system. He proposed to reshape the educational goal in the intelligent era, vigorously promote the digital transformation of education, and strengthen the opening and cooperation of smart education to achieve the sustainable development goals of education.

Colleges and universities play an important role in the reform and development of education. **Mr MA Jun**, the President of Beijing Normal University, pointed out several important issues:

- more attention is needed for the teachers training in rural areas, especially in remote and ethnic areas;
- there is a need to actively promote the transformation of teachers' roles and improve teachers' digital literacy;
- rely on AI, big data, virtual reality and other technologies, and provide supports for the pre-service and post-service integration reform of teacher education;
- local government and school leaders should design smart campus and a new generation of the learning environment; and
- encourage teachers to be proactive in the front line of teaching and be able to carry out research to provide solutions for the better integration of intelligent technology into education and teaching.

Professor ZHAO Qinping, the Academician of theChinese Academy of Engineering, pointed out the current digital transformation of education and smart learning are becoming a new stage for the development of education informatization. In the process of the systematic reform of education, the digital ability of teachers, students and managers is the key focus. Users are the most important factor in education. Therefore, technology should be applied by users to serve teaching and improve people's digital literacy and skills. The innovative development of education informatization is a systematic project. It is important to seize the opportunity of new infrastructure construction in education and provide digital learning content, platforms and tools for better teaching and learning to improve the level of digital education services and governance.

The First Deputy Prime Minister and Minister of Education, Science and Technological Development in Serbia, **H.E. Mr Branko Ruzic**, expressed the practical exploration of China's digital transformation of education had brought great inspiration to Serbia. Serbia is actively improving the construction of educational infrastructure, enhancing the digital ability of schools, teachers and students, promoting the digital transformation of education, and improving the flexibility and quality of education.

The Senior Special Assistant to the President on SDGs in Nigeria, **HRH Princess Adejoke Orelope-Adefulire**, stressed that high-quality education is the best investment, in which everyone can receive an education in a healthy and sustainable society. The Nigerian government is implementing the requirements of the United Nations SDG4 in increasing investment in education, eliminating the digital divide, and promoting the supply of sustainable educational resources. She also referred to the cooperation between Nigeria and the Chinese Digital Technology Company that had played a positive role in curriculum reform and the improvement of teachers' teaching levels.

The Deputy Minister of Education in Turkmenistan, **H.E. Mr Azat Athalye**, noted that the application of digital technology in education is a trend for future development. With the development of network technology, online learning methods and traditional education models will gradually be integrated.

Turkmenistan is committed to building a digital education system, improving the digital infrastructure, establishing an international cooperation network, and promoting the technological upgrading of the education system.

UNESCO is committed to helping and supporting the planning and practice of member states in the field of AI and education, building a global education cooperation network, ensuring inclusive and equitable quality education, and promoting lifelong learning opportunities for all. **Professor ZHAN Tao**, Director of UNESCO IITE, pointed out achieving this goal depends on the joint efforts of global partners. He believed China's forward-looking plans and innovative practice presents encouraging examples. UNESCO IITE and Beijing Normal University have carried out close cooperation. In particular, since the outbreak of COVID-19, the two sides' exploration of smart education has received strong support and positive response from experts and scholars around the world.

Rethinking and Redesigning National Smart Education Strategy

At the opening ceremony, on behalf of the project expert team, **Professor HUANG Ronghuai**, who is the Co-Dean of the Smart Learning Institute of Beijing Normal University, reported the research results of "Rethinking and Redesigning National Smart Education Strategy" and launched the "Initiative for GSENet".

The "Rethinking and Redesigning National Smart Education Strategy" was jointly launched by the UNESCO Institute for Information Technologies in Education (UNESCO IITE), Commonwealth of Learning (COL), International Society for Technology in Education (ISTE), National Research University Higher School of Economics (HSE) and Beijing Normal University (BNU). Various institutions worked together to sort out the experience of smart education in various countries and explore the development strategy of smart education. It has formed a series of research achievements such as the National Smart Education Framework, the Global Smart Education Policy Analysis, the National Smart Education Evaluation index, the National Public Service System for Smart Education, and the Smart Campus Design for Future Education.

In order to better promote the development of global smart education and effectively promote the digital transformation of education, the project research team gives five suggestions for the future development of smart education:

- teachers, managers, and stakeholders should recognize the important role of smart education;
- governments should promote the development of smart education according to strategic levers;
- policymakers should review, analyze and formulate relevant national education policies from the aspects of information infrastructure, digital education resources and platforms with the goal of smart education;
- local government and school leaders should design smart campus and a new generation of the learning environment; and
- all stakeholders should promote and strengthen cooperation under the smart education strategy.

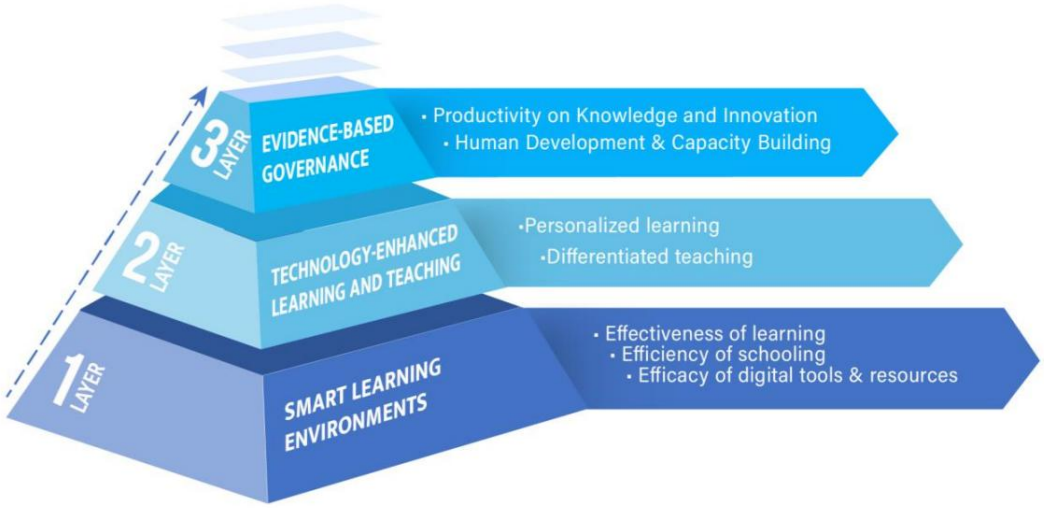
Initiative for Global Smart Education Network (GSENet)

During the conference, the "Global Smarter Education Network" (GSENet) was officially launched aiming to establish an international smart education network of researchers, practitioners, technical experts and policy makers to support countries in rethinking and designing

education systems at the national, regional and school levels. The rapid development of big data and artificial intelligence has made an increasingly deep impact of technology on society. Adapting individuals and communities to the uncertain and complex future is an important issue in educational development. Moreover, smart technology contains huge potential for change, which needs to be transformed into an effective and practical way through smart education. **Professor HUANG Ronghuai** said: "The world needs to conduct joint research and exploration on smart education, form strategies and solutions to reshape and innovate education, and establish an equal, inclusive and high-quality smart education to meet the diverse and personalized needs of everyone in the future."

The network is composed of Beijing Normal University, UNESCO Institute of Information Technology in Education (UNESCO IITE), Arab League Educational, Cultural and Scientific Organization (ALECSO), Commonwealth of Learning (COL), International Society for Technology in Education (ISTE), and the Southeast Asian Ministries of Education Organization (SEAMEO). The Smart Learning Institute of Beijing Normal University serves as the secretariat of the network. The network will conduct consultations and discussions on the development of smart education in various countries, and promote the integration and innovation of the new generation of information technology and education.

In the future, the "Global Smart Education Network" will promote the deep integration of a new generation of information technology and education, and promote equal and inclusive high-quality education for all, lead the development of global smart education from the aspects of concepts, methods and systems, promote a balanced, equitable and high-quality development of education in various countries, respond to UNESCO's "Future of Education" initiative to reach the SDG 4 targets.



Three layers of Smart Education

Initiative for Global Smart Education Network (GSENet)

GSENet Vision

Looking to 2030 and beyond, GSENet seeks to leverage emerging technologies to promote equal and inclusive high-quality smart education for all to achieve the targets of SDG 4, with the vision: Networking with the best for a global smart education to ALL

GSENet Mission

- To connect educational technology organizations for disseminating generic policies and innovative strategies at national, regional, and school levels towards achieving SDG 4 targets;
- To promote state-of-art technologies, practical experiences, and best practices to serve researchers, teachers, and technicians in supporting the development of smart education.

GSENet Activities

- To hold official conferences and present outcomes from the GSENet for sharing innovative ideas and best practices to GSENet members and beyond;
- To create a set of toolkits for assessment and monitoring to support GSENet members with IT solutions in Smart Education by using academic and practical experiences from Ministries of Education;
- To produce annual report of GSENet community disseminating the status of Smart Education in each region from the network;
- To offer guidance, in association with UNESCO IITE E-Library, on OER, OEP and Smart Learning by providing tutorials to customize resources for the regions who are joining the GSENet;
- To conduct teacher and technician training programmes in cooperation with GSENet member organizations (ALECSO, SEAMEO, COL, ISTE, IASLE, and others) by using and establishing training centers in the GSENet regions.

GSENet Organizations

Founding Members

- Beijing Normal University (BNU)
- UNESCO Institute for Information Technologies in Education (UNESCO IITE)
- Commonwealth of Learning (COL)
- Arab League Educational, Cultural and Scientific Organization (ALECSO)
- International Society for Technology in Education (ISTE)
- Southeast Asian Ministers of Education Organization (SEAMEO)

The Secretariat

Smart Learning Institute of Beijing Normal University (SLIBNU)

Academic Board

- The Academic Board has representatives from each GSENet member and is responsible for the development, agreement, and oversight of the academic standards, regulations, and quality of research projects and programs for Smart Education.
- The member of the Academic Board includes the distinguished scholars and scientists, the academic coordinators of each member institution, and any experts recommended by the members of the Academic Board.

Digital Transformation for Smart Education

In recent years, the construction and application of education informatization in China have continued to advance. The Chinese government has released strategic and policy documents such as *China's Education Modernization 2035 plan, The New Generation Artificial Intelligence Development Plan*, *Education Informatization 2.0 Action Plan*. The Chinese Ministry of Education's annual work points include the proposal of implementing the strategic action of education digitalization as well as accelerating digital transformation and intelligent upgrading. The strategic significance of digital transformation in education is in the same vein with digital China and digital economy.

Digital Transformation for Smart Education requires us to rethink the talent training from the perspective of building a smart society, to optimize and upgrade the digital learning environment, to transform the teaching and evaluation model, to promote the innovation of systems and mechanisms, to establish an inclusive, fair, green, high-quality and sustainable intelligent educational system that adapts to the intelligent era, and to improve the lifelong learning system that enables all learners to learn at anytime, anywhere.

Mr LEI Chaozi, Director of the Department of Science, Technology and Information, Ministry of Education, delivered a speech on "Seize the Opportunity of Digital Transformation and Build a New Ecology of Smart Education". He pointed out the digital transformation of education is not only essential for building a digital China, but also a strategic choice to seize the climax development. It is also an internal demand for the high-quality development of education, and

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President of UNISEDU, China

1 See https://www.smartedu.cn/

the only way for China's education to rise from a basic equilibrium to a high-level equilibrium, and from an educational country to an educational power. At the beginning of this year, the Ministry of Education of the People's Republic of China made an important deployment for the implementation of the national digital education strategy, focusing on building the platform of *Smart Education of China* . The construction and application have gradually risen, which will help accelerate the systematic reform of education and comprehensively realize the digital transformation of education. He mentioned in order to jointly cope with global crises and challenges, we should further stimulate and release the vast energy of technology and education integration, strengthen international exchanges and cooperation, contribute to global education development and the realization of the 2030 education goals, and highlight the responsibility and undertaking of the education system in building a community with a shared future for mankind.

The Chinese Ministry of Education launches National Smart Education Platform [2]

The MOE held a ceremony to launch the National Smart Education Platform on March 28, 2022. Minister of Education Huai Jinpeng attended the ceremony and announced the official launch of the platform.

The minister said that the launch of the platform, as a milestone achievement of the education system in advancing digitization, would greatly help bridge the "digital divide", and generate more momentum for the ongoing digital transformation of China's education system. He urged local educational departments to promote the use of the platform and explore other IT solutions in order to help build modern educational infrastructure. As a next step, he said a public service system for educational digitalization would be built, prioritizing services for students and teachers amid a new round of COVID-19 outbreak. A result-oriented approach and a focus on effectiveness and efficiency would be vitally important, he said. In addition, institutional mechanisms had to be strengthened to bring together all stakeholders in building this service system. Cooperation and exchanges with the rest of the world would also be necessary, as China strives to be an international leader in smart education.



The platform comes with easy-to-use applications and tools tailored to the needs of school students and offers abundant digital resources.

2 See http://en.moe.gov.cn/news/press_releases/202204/t20220411_615580.html

Professor GONG Ke, Executive Dean of Chinese Institute of New Generation Artificial Intelligence Development Strategies (CINGAI), pointed out the digital transformation of education is the digital innovation of teaching tools and the digital reform of teaching content and teaching mode. The success of digital innovation of teaching tools hinges on the research and development of teaching facilities using digital technology. The success of the digital reform of teaching content and mode requires a sound digital technology curriculum system, as well as an open, inclusive, multidisciplinary, and problem-oriented learning environment. He proposed three measures:

- putting a premium on basic subject learning and integrating interdisciplinary and cross-field knowledge transformation
- combining technical and social attributes in the teaching process to promote learning through practicee; and
- developing a team of qualified teachers with expertise and responsibility.

Professor ZHANG Jingzhong, the Academician of the Chinese Academy of Sciences, pointed out in his report titled"Intelligent Mathematics Education Technology for In-depth Disciplines" that the basic education software of disciplines is full of vitality, and the mathematical intelligent education software could alleviate the burden of teaching and make learning enjoyable. He believed there are five ways for intelligent mathematics education technology to facilitate the digital transformation of education:

- building a digital and intelligent teaching resource operating environment;
- staying open and integrated to upgrade educational resources and software and hardware products;
- co-creating and sharing resources and shifting from a supply-driven model to a demand-driven model;
- building an application environment for the integration of mathematics teaching and learning, i.e., an Internet Mathematics Laboratory;
- building a technological model with intelligent mathematics education technology to change the way of teaching and learning.

Digital transformation is essential for educational reform and progress. The integration of IT into education and teaching presents new challenges for the role of teachers, their relationship with students, and the learning process. **Professor ZHONG Binglin**, the committee member of the State Education Commission of P.R.C, indicated the support of the digital economy talent pipeline, fundamental theories, and critical technologies are desperately needed for the digital transformation. He further noted that it is necessary to assemble a high-quality and professional faculty through systematic project research and development, curriculum training, etc., and comprehensively improve teachers' informatization and digital literacy. The rapidly developing digital economy has given rise to a critical governance proposition for the digital transformation of education. He stressed that it is necessary to actively respond to the new challenges for the digital transformation of education, including rethinking what education should be and how to deliver it, strengthening team building, and optimizing the governance system.

Professor ZHENG Qinghua, Vice President of Xi'an Jiaotong University, talked about the fourth industrial revolution and educational innovation, and emphasized the new generation of information technology, represented by AI, is rapidly catalyzing the fourth industrial revolution and setting off a new wave of the industrial revolution – technological revolution – which in turn reshapes the education revolution. He

analyzed the historical revelation of the development of higher education, discussed the new missions and challenges imposed by the new era, and put forward critical tasks and measures for future innovation based on the status quo. This included a profound understanding of education laws and direction; focusing on the fourth industrial revolution to innovate discipline and major setting; strengthening the training of talents in fundamental disciplines; emphasizing the deep integration of theory and engineering practice; vigorously utilizing AI and other technologies to empower educational innovation and development.

Mr Renato Opertti, the senior expert from IBE-UNESCO, made a presentation on "Curriculum Reform in the Post-pandemic Era." He introduced the Chinese version of the "Guidance Framework for Blended Education, Learning, and Evaluation" issued by the IBE-UNESCO and Smart Learning Institute of Beijing Normal University. The framework identifies key strategies for implementing blended education, learning, and evaluation, as well as providing principles for reforming the curriculum and the teaching practice. It also extensively adopts technologies to facilitate blended learning of teaching, learning, and evaluation He mentioned about flexible teaching, promoting the development of human potential and the distribution of equal educational opportunities, which eventually leads to contributing to the realization of Sustainable Development Goals.

Professor Rebecca Eynon from the University of Oxford shared her views on the challenges and possibilities of using smart technologies for education. She suggested we move away from a very strong focus on educators and what educators believe the future of education should look like but more to thinking about the growing role of computer scientists, physicists, and engineers in this space, who have much of thetechnical capabilities. Looking into the future, she listed five key elements for shaping the future direction with respect to thinking about smart technologies: understanding the changing ecology of education, building systems that facilitate agency and applying the logic of augmenting expertise, ethics, fairness, accountability, and transparency.

Professor Rory McGreal, UNESCO/ICDE Chair in Open Educational Resources, delivered a report and shared his practical experience focusing on micro-credentials, open educational resources, and digital transformation. He noted that the difference between micro-credentials and regular credentials is that the latter has short duration, narrow in scope, and for educational or training activities. Behind micro-credentials is the possibility for learners to develop their own personal pathways to formal credentials such as certificates or degrees. He believed one of the reasons for high demand of micro-credentials is the need to provide short-timeframe opportunities for upskilling and reskilling.

The prevalence of new business and service models and enterprises plays an essential role in the tech-driven digital transformation of education. It also provides ubiquitous cloud and intelligence support and solutions for educational activities. **Mr WANG Hongtao,** the President of UNISEDU, believed technological innovation is crucial to developing the digital economy. In addition to the introduction of talents, technology enterprises need to implement personalized learning and large-scale individualized teaching through the bi-directional empowerment of education and technology to bridge the digital gap and foster the development of innovative talent of the highest caliber.

Digital Transformation for Smart Education
Key takeaways

- Equipping schools with appropriate ICT infrastructure and promotion of the flexible physical spaces during the use of technology are the basic prerequisites for the implementation of innovative approaches to teaching and learning.

- Until we tackle this digital education divide, together with the (rural-urban) divide, generation divide and gender divide, the opportunities offered by the digital transformation of education will remain out of reach for billions.

- The future of education lies not in the partial changes or marginal innovation of the existing education system. Rather, it will be a brand new educational ecosystem that is developed to promote learning, literacy and abilities.

- The digital transformation of education is a process of promoting the deep integration of digital technology and education. That is using digital technology to renew educational concepts, transform education models, and promote intelligent upgrading.

- In the development of education informatization, although factors such as environment, resources, and data are important, the most significant one is "people". Technologies shall be used by people and served the teaching and learning process for teachers and students.

Teacher Education in Metaverse World

Education is one of the main fields of designing innovative metaverse world, providing an immersive and interactive teaching and learning experiences for teachers, students, and other educational stakeholders. It also meets the teaching and learning needs of teachers and students in both the physical world and the virtual world. Carrying out the metaverse research in the field of education will help to further clarify its connotation and future trend, and provide new ideas for seeking a high-quality educational development path, reshaping the relationship between education subjects, and solving problems such as educational equity. As the users of the metaverse, teachers shall explore how metaverse could be applied in teaching, evaluation and management, which would help them better adapt to the development trend of technology-empowered educational innovation and change.

Professor ZHU Xudong, Dean of the Faculty of Education of Beijing Normal University, believed the new technology is expected to significantly impact teaching scenarios, teaching resources, teaching organization and evaluation through the deep integration of virtuality and reality, online and in-person teaching. Such technology not only brings new opportunities for teacher development but also makes new requirements for teaching ability. Courses on teacher education and instructional methods need to be upgraded and innovated to respond to the opportunities and challenges brought by the changes of the times and technological development.

Professor Getachew Engida, Former Africa Assistant Officer of UNESCO, highlighted that the era of sustainable development calls for innovation, which comes from new systematic

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Prof. Stylianos Mystakidis
University of Patras, Greece

Dr. Lik-hang Lee
Assistant Professor, Korea Advanced Institute of Science and Technology, Korea

Dr. Gaana Jayagopalan
Associate Professor, Alliance University, India

thinking, new operating methods and technologies. There is a long way to go to achieve the goals set by the 2030 Agenda for Sustainable Development. The international community will make joint efforts to explore the potential of technology and innovation.

The Potential of the Metaverse in Education and Teacher Professional Development

Professor CHEN Zhong from the School of Computer Science of Peking University delivered a keynote speech on "The path of innovative development of the integration of metaverse and Web 3.0". He pointed out the metaverse provides new development opportunities for future education. He systematically discussed the role of blockchain played in the metaverse in education and shared the innovative application scenarios of the metaverse and Web3.0.

Mr Awol Endris Adem, Education Programme Specialist at UNESCO Regional Office for Eastern Africa, highlighted the issues on teachers, the digital divide and the metaverse. He proposed that teachers shall be equipped with better digital skills to teach in the metaverse world; otherwise, the use of new equipment and technologies will bring much cognitive load to teachers. Metaverse can also enrich teaching content and provide support and assistance for teacher training.

Professor LIU Geping, the Vice Chairman of China Higher Education Information Academy (CHEIA), focused on "Metaverse-supported Teacher Development Scenarios" and gave further elaborations, including the scenarios of simulating teaching trials, improving teaching adaptability, rehearsing classroom management, promoting teaching interactions,enhancing the ability of empathy, and supporting teaching reflection.

Ms Annie Ning, Director of Asia Affairs of International Society for Technology in Education (ISTE), cared about how to improve students' learning motivation. Taking the subjects of Chinese, mathematics, and English as examples, she emphasized the influences of scenes, tasks, games, and other factors on students' learning motivation through a detailed explanation of several teaching cases, which inspires the innovative design of pedagogic activities.

Dr. Temechegn Engida, Programme Officer at International Institute for Capacity Building in Africa (IICBA), shared his thoughts on “Capacity Building of Teachers and Teacher Educators in e-Learning Content Development and e-

Assessment in Africa" based on his working experiences at IICBA. In Africa, the traditional approach to e-learning costs a lot for teachers, and teachers are only seen as consumers of digital content. He encouraged teachers to set up teams, use affordable technologies to design curricula and work together on the analysis, design, development, implementation, and evaluation of e-learning content.

Mr CHEN Hong, Senior Vice President of NetDragon, shared his thoughts and practices on the great technological convergence of metaverse in education. He presented a video on the metaverse to let audiences experience how the metaverse is applied in real-world teaching and pointed out the advantages of the metaverse, such as promoting personalized learning, stimulating learning interests, enhancing learning effects, and optimizing experiment or training modes. He also introduced how the teaching content is produced for the metaverse world from a technical level.

Professor Colin De La Higuera from the University of Nantes in France focused on Artificial Intelligence and Open Education. He introduced some ongoing projects, including Open Education Global 2022, FLORILEGE, and Multiling-OEG, based on which he reflected on the project practice about "industrial takeovers education" and "the supervision of open education resource".

E-Library for Teachers: Helping Global Teacher Capacity Building

Since its release in 2021, the project "E-Library for Teachers" has provided teachers around the world with services in several languages, such as open educational resources and educational training, opportunities for communication and interaction, and resource co-construction and co-sharing. It covers five regions, including Eastern Europe, Asia, Africa, the Middle East and the Commonwealth of Independent States, and benefits nearly 100,000 educators.

E-Library for teachers[3]

To boost teacher ICT competency development, provide educators with advanced digital resources and AI-based educational solutions, strengthen teaching networks, and overall contribute to capacity building in target regions, UNESCO IITE and a global leading creator of Internet communities NetDragon have joined efforts to create the online platform. This platform represents a hub that serves as a resource and training as well as, communication and networking center for teachers around the globe with open education resources in English and Russian languages (Arabic is coming soon). For over a year partners and members of the project team have been working together to bring this platform to life. In order to amplify the impact of the platform and provide teachers with quality resources, IITE reached out to international organizations holding expertise in the upliftment and empowerment of educators worldwide.

On June 8, 2022, UNESCO IITE and NetDragon officially launched the "E-Library for teachers" to the high officials and partners such as the representatives of the Ministries of Education from the target countries: the Republic of Serbia, the Republic of Tunisia, the Republic of Ghana, the Arab Republic of Egypt, the Russian Federation, the Kingdom of Thailand and partners from BNU, the COL, ISTE, Autodesk, ALECSO and Go-Lab.

3 See https://iite.unesco.org/highlights/official-launch-of-the-platform-e-library-for-teachers/

Application and Innovation of Educational Metaverse Scenarios

In this part, experts and scholars from the Netherlands, Romania, Greece, India and other countries conducted in-depth discussions on the application of metaverse in various teaching scenarios.

Professor Ton de Jong from the University of Twente in Netherlands introduced Go-Lab - an Ecosystem for Inquiry-Based Instruction. He first pointed out the existing problems in STEM education and believed Go-Lab could create effective teaching scenarios for teachers. As an online learning platform, Go-Lab can not only be embedded with multimedia teaching resources and software but also support students to co-share resources and solve practical problems faced by teachers in STEM education.

Professor Elvira Popescu from the University of Craiova in Romania paid close attention to peer assessment platform for smart education. She argued that although peer assessment is essential for students and teachers, it raises issues of authenticity, validity and fairness. She introduced the “LearnEval” peer-evaluation platform and the results of case studies. She believed the future development trend of peer evaluation platforms is to strengthen the intelligence of the platform and realize real-time peer evaluation and feedback.

Professor Cynthia Calongne from Parker University in USA highlighted the advantages of the metaverse in education. The application of metaverse can not only help teachers create virtual learning environments but also help students enhance peer perception and the ability of collaborative communication. The future development of the metaverse shall strengthen its relevance to the real world and technological innovations in order to provide students with more efficient tools.

Researcher Stylianos Mystakidis from the University of Patras in Greece gave a presentation on “Motivation-enhanced Smart Learning in the Metaverse”. He believed the metaverse is a bridge to promote the transformation of education and instructional mode. In this context, gamification design, toys and interesting design can better enhance students' learning motivation and promote intelligent learning.

Dr. Lik-hang Lee from the Korea Advanced Institute of Science and Technology reported on " When Education meets the Metaverse: an overview and challenges". He analyzed the three stages of metaverse development and how to build the metaverse world; then, he introduced some classic cases like Roblox, Minecraft, Facebook workshops,etc. He finally shared his views on the challenges facing the metaverse in education, such as issues on a hardware device, students' social presence, and student interaction and feedback.

Dr. Gaana Jayagopalan from the Alliance University in India delivered a speech on “teaching through urban sensorium: urban spatiality as a smart learning environment”. She proposed we should change the conception that teaching only happens in traditional classrooms and extend learning space to urban buildings as the urban spatiality may provide possibilities for intelligent teaching.

Teacher Education in Metaverse World
Key takeaways

- The discipline of teacher education is an academic field. Teacher education should carry out academic research on the priorities, difficulties, hot spots and frontier issues in the field of teacher education, and form a subject knowledge system to serve the theory and practice of teacher education.
- The lack of training and proper qualification of teachers will very likely result in poor learning by students as the countries do not have the resources to equip schools with required teaching and learning materials – enough classrooms, textbooks, lab equipment, supplementary materials, etc.
- The metaverse can provide each user with a variety of modeling tools, which allow them to create their own content of interest. This is helpful for training pre-service teachers, who can use such technology to create a learning/teaching environment that best suits them.
- The primary focus of e-assessment is not developing new assessment tools but improving learning by using new assessment technologies.
- With the development of AI, in the future, every student will be able to have their own virtual education partner in the metaverse world, and can also have personalized education anytime and anywhere.

Digital Literacy in Smart Learning Environment

With the smart technologies such as artificial intelligence (AI), the Internet of Things (IoT), and big data continuing to mature, these technologies have penetrated into all areas of human activity, changing the way they produce, live, and learn. The widespread deployment of smart technologies is considered a core competitive advantage of sustainable development. At the center of this ecosystem of smart technologies is the users, aiming to improve digital literacy and promote smart learning. As a result, all levels of educational institutions around the world are challenged by the incremental or disruptive digital transformation and intelligent upgrading.

At the same time, in the wake of the COVID-19, distance learning has become a new reality in school education around the world, and blended teaching has been widely adopted in K-12, higher education, vocational education and lifelong learning. To this end, it is necessary to analyze the application scenarios of sustainable smart education and conduct dialogues around differentiated education and personalized learning with intelligent technology, including the issues on digital literacy and skills, technology-empowered smart learning, teaching innovation and smart learning environments, which provided new ideas and directions for countries to further improve citizens' digital literacy and promote smart learning practices.

Mr WANG Yongli, Deputy President and Secretary General of the China Education Association for International Exchange, expressed his expectations for the interconnection of higher education between

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Academic Network for Education of CCHEIC

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regions. He noted that under the framework of the China-Central and Eastern European Universities Federation, China Education Association for International Exchange would fully support the international exchanges and cooperation between Chinese higher education institutions and those in Central and Eastern Europe, aiming to promote the high-quality development of global higher education.

Professor Vladan Đokić, Rector of the University of Belgrade, said that the University of Belgrade and Beijing Normal University have extensive cooperation foundations and close ties in the field of smart education. He expected the two sides would carry out more in-depth cooperation in the field of educational technology.

Academic Network for Education of CCHEIC

Professor YU Kai, Vice Dean of the Faculty of Education of Beijing Normal University, launched the "Academic Network for Education of CCHEIC", and introduced the concept and action plan of the community construction.

Professor Danimir Mandić from the University of Belgrade and **professor Demetrios Sampson** from the University of Piraeus hoped to strengthen the exchanges between universities, research institutions in Central and Eastern European countries and Chinese universities in the field of education, which aimed to promote the sharing of high-quality educational resources, deepen the pragmatic cooperation between countries in the aspects of educational theory research and educational practice innovation, and finally contribute to building a community with a shared future for mankind. metaverse in education, such as issues on a hardware device, students' social presence, and student interaction and feedback.

The Academic Network for Education of China-CEEC Higher Education Institutions Consortium(CCHEIC)

China-CEEC Higher Education Institutions Consortium was established in 2014. On the basis of adhering to the "mutual respect, equality and mutual benefit, and win-win cooperation" principle, the Consortium plays an important role in enhancing educational exchanges and cooperation between China and central and Eastern European countries. China Education Association for International Exchange (hereinafter referred to as "Association"), as the Chinese Secretariat, continues to expand the influence of the Consortium, gives full play to the initiative and enthusiasm of its member universities, and plans to implement the classified management of the academic network. As the co-founder, Beijing Normal University applies to initiate the Academic Network for Education of China-CEEC Higher Education Institutions Consortium. Beijing Normal University is responsible for absorbing Chinese and foreign universities in the educational field; planning cooperative projects to jointly build and promote the development of educational disciplines; and manage the activities of member universities in the academic network.

- **Goal**

  Relying on the platform of Consortium, the academic network aims to strengthen academic exchanges and cooperation in the field of educational disciplines between China and CEE countries; to carry out cooperation in brand projects, and build a network for academic cooperation and exchanges among member universities; to promote the sharing of high-quality educational resources, and to support international joint research; raise the internationalization level of educational research and practice; cultivate innovative talents with global competence, and make greater contribution to building a community with a shared future for mankind.

- **Mission**

  Under the guidance of the Bucharest Guidelines for Cooperation between China and Central and Eastern European Countries, the academic network focusing on the work of Opening-up of Education in the new era and following actual needs of educational discipline development in China and CEE countries. Abide by the principles of mutual learning, co-building and sharing, cooperation and development, through "building platforms, sharing resources, building brands, and joint output" series activities, the academic network will strengthen exchanges and cooperation in education disciplines between China and CEE countries, and jointly cultivate innovative talents with strong abilities to meet global challenges.3

- **Obligations**

  - The Association is responsible for managing and supervising of all community work, including to determine the sub-group plan of the Consortium and issue the working methods; monitor and review the work of the academic network; to provide necessary assistance as required by the academic network universities; and participate in the annual meeting, etc.

  - Beijing Normal University is responsible for coordination of the members and carrying out activities within the academic network, including organizing the management and working team; drafting the application methods; planning and designing cooperation projects and annual development plans; developing universities in China and CEE countries as Consortium member universities; organizing academic activities and monitoring the progress of cooperation projects; and working on the annual summary of academic network activities.

- **Work Plan**

  - Establishing academic network team and build a cooperative network, including establishing academic network team and creating cooperation and exchange brand projects. First, relying on the Consortium and other platforms to issue member recruitment announcement, inviting Chinese and foreign institutions to join the Academic Network for Education; second, through the existing network of domestic universities to develop partner universities with educational discipline in CEE countries to join the community. By holding seminars, symposiums, and forum activities, more universities will be invited to join the community and gradually a network of cooperation platform will be built. For the latter, the academic conference of the Academic Network for Education of China-CEEC Higher Education Institutions Consortium will be hold annually, providing a platform to discuss related educational discipline issues in China and CEE countries. Create joint research projects for teachers from community member universities; plan student design competition, cross-cultural exchanges and student forums for student, and gradually establish a multilateral interaction mechanism through the development of cooperation and exchange projects.

  - Sharing educational resources and cooperating to cultivate talents, including implementation of high-quality education resource sharing projects, cooperative development of postgraduate courses, organizing student exchange programs, and conducting campus cultural activities of mutual learning and appreciation to enhance the global competence of students.

  - Strengthening joint scientific researches and joint publications in the Academic Network for Education. Consolidating the existing virtual joint laboratory for future education in China-CEE countries, attract researchers from member universities to participate in international cooperation research through joint international researches and joint publications, and establish the China-CEE community for intelligent education. The corresponding joint researches will be carried out by relying on the advantageous sub-disciplines of pedagogy of Beijing Normal University. Initially, it is planned that the Institute of International and Comparative Education will take the lead in conducting China-CEE education country studies and comparative education studies; the Institute of Education History and Culture will take the lead in conducting research on the history of education in China-CEE countries; other sub-disciplines of pedagogy of Faculty of Education, such as teacher education, vocational education, special education and other fields, can apply joint research projects. Through joint research projects, researchers from various disciplines of higher education in China and CEE are connected to study common concerns from different perspectives and promote the development of educational disciplines.

  - Carrying out workshops for principals and teachers of primary and secondary schools in China-CEE countries. Investigating the professional development needs of primary and secondary school principals and teachers in CEE countries to design professional development training programs for different groups of educational personnel. Setting up a team of education experts from China-CEE countries to conduct principal and teacher training in the form of cooperative training programs.

  - Providing theoretical support and professional guidance for the China-CEE Education Community. Gathering the wisdom of talents from all sides to build a talent think tank of “The Academic Network for Education of China-CEEC Higher Education Institutions Consortium” to provide policy consultation and intellectual support for China and CEE countries in the field of educational disciplines strategic planning, educational development at all levels, people-to-people and cultural exchanges and other aspects.

Academic exchanges on smart education between China and (CEEC)

At this forum, 12 experts from 9 countries shared their understanding of the characteristics of smart education, as well as the latest situation and practice of smart education development in China and Central and Eastern European countries.

Ms ZHUANG Rongxia, Associate Professor from Beijing Normal University, focused on international comparative research on the development of smarter education. Based on the cooperative research results from China, Serbia, Greece, and other countries, she analyzed the overall characteristics and characteristics of smart education practices in various countries and pointed out that smart education can be promoted from 3 aspects: the construction of smart learning environments, the reform of teaching and learning, and educational policy and governance. She held that smart education is a long-term, systematic, and continuous work that requires the joint efforts of all countries.

Professor Sandra Kucina Softic from the University of Zagreb elaborated on the advantages and challenges of digital transformation in Education. She believed the digitization of education has made teaching resources available to more learners on a global scale; as a result, students have a wider range of learning opportunities, and the learning process is more personalized. She also stressed that the digital transformation of colleges and universities needs to redevelop the operating model and integrate "digitalization" into education in an all-round way, rather than just adding high-quality digital infrastructure.

Mr Borut Čampelj, who is from the Office of Development and Education of the Ministry of Education, Science and Sport in Slovenia, gave his view on the topic of “Towards Smart Education". He believed smart education needs to consider the factors like smart curriculum, teaching environment, pedagogic methods, teachers, leadership team, etc. Smart education shall be developed with the aim to benefit various communities and promote ubiquitous, equitable and quality education.

Professor Gyöngyvér Molnár from the University of Szeged in Hungary gave a presentation on "Applying Intelligent Technology to Make Education Smarter". She proposed that intelligent education should be evidence-based, data-driven, and constantly adapt to students' individual needs. She emphasized that summative assessment cannot meet the individual needs of students, and it is necessary to develop complex, practice-integrated, high-quality assessment methods and tools to replace the traditional "one-size-fits-all" method.

Professor WANG Yunwu from Jiangsu Normal University said that many countries around the world had implemented digital education strategies, which accelerated the digital transformation in education. The two-way empowerment of technology and education will further accelerate the digital transformation in education, form an ecological chain of digital education, and promote the development of the digital economy and smart society.

Dr. Diana Andone from the Politehnica University of Timisoara in Romania highlighted “Digital Future Universities 2030”. She introduced the framework for developing digital education strategies for universities. The framework includes 3 areas: “Vision, Leadership, Governance”, “People, Community, Stakeholders”, and “Tools, Spaces, Resources.” She also suggested that the collaboration and openness of all stakeholders shall be empowered, the sense of community needs to be created, and the infrastructure shall be scaled up.

In addition, five speakers shared their views on the development of smart education in their own countries, including **professor Siyka Chavdarova-Kostova** from Sofia University "St. Kiment Ohridski" in Bulgaria, **Dr. Maja Homen** from the University of Zagreb in Croatia, **Dr. Engjellushe Zenelaj** from the Reald University of Vlora in Albania, **Ms Ana Sekulovska** from the University of Tourism and Manegement Skopje in North Macedonia, and **professor Charalampos Karagiannidis** from the University of Thessaly in Greece.

In Bulgaria, in recent years, there has been a clear tendency the integration of ICT to be prioritized at all levels of the education system in Bulgaria - from preschool to secondary and higher education. Manifestations of this trend can be found in various strategic and regulatory documents related to education policy. Bulgaria's digital transformation is not only a desired perspective, but also supported as a strategic vision until 2030. The development of artificial intelligence is an integral part of this vision. It is an undoubted priority at the strategic level not only in the activities of the Ministry of Education and Science. Efforts at the national level in the construction of digital infrastructure continues. In general, the development of smart education in Bulgaria has its foundations. There are visible prospects for development that would increase the quality and efficiency of secondary and higher education.

In the Republic of Croatia, since independence as well as since the beginning of the process of accession to the European Community, a lot has been done in the field of education. By accepting the Bologna Process as well as the development of new Digital Educational Technologies, the basic elements of the development of education at all levels have been set, from pre-school programs, higher education university programs to adult education.

In the Republic of North Macedonia, The national vision and plan includes the priorities of improving the system for collecting statistical data and EMIS (Educational Management Information System) and ensuring widespread use of ICT in education and training and digital literacy. For EMIS, it is not only a web-based tool for collecting, processing, checking and presenting data and information that are important in the educational process in primary and secondary education in North Macedonia, but also a comprehensive system that connects people, practices and technology in order to provide quality educational statistics in a short time, in an efficient and sustainable way at every administrative level. For ICT in education, the Republic of North Macedonia sets relevant policies. For example, one of the goals of *the Education Strategy for 2018-2025* and the Action Plan is to intensify the application of ICT in education by establishing an e-learning portal and system for managing learning and continuous training of new tools and staff in education, and building a system for recovery of computer equipment and providing conditions for efficient maintenance of computer equipment and computer networks.

In Albania, Albania currently has several efforts to integrate technology into the education system. These are sporadic efforts that mostly stem from collaborations with NGOs for pilot programs or for some educational institutions. Challenges of Albanian education system in the process of systematic integration of technology and education:

- during the last years, changes have been made in the textbooks where there is a combination with technology, but during the last 5 years, from a statistical point of view, there has been a decrease in investments for technological equipment in educational institutions;

- there are also no investments or development programs for teachers or for various technological applications for the teaching process;

- in Albania we still do not have real electronic libraries to create opportunities for pupils or students as well as teachers to research the learning process.

In Greece, Greece published *The Greek Digital Transformation Bible (2020-2025)*. It is a holistic digital strategy which describes the objectives and implementation measures of the digital transformation strategies. One of the objectives is the development of digital skills for all citizens.

In this regard, Greece transforms education through MOOCs. For enhancing teachers' and students' digital competency, HyperMOOC is established for teaching and learning in online and hybrid inclusive education format. The design principle of the HyperMOOC is the European framework for the Digital Competence of Educators (DigCompEdu), which synthesizes national and international efforts to capture educator-specific digital competencies, and proposes a six level progression model to help educators assess and develop their digital competences. For K-12 education, PROG-MOOC is established for computer science for high school students as a supplementary resource to the existing school curriculum.

Digital Literacy in Smart Learning Environment
Key takeaways

- Digital learning environment empowered by intelligent technologies (e.g. seamless connectivity, digital learning devices, etc.) can promote smart education. Formal and non-formal education opportunities are enabled and accelerated in such environment, and learning could occur anytime and anywhere.

- Technology enables the transformation of teaching and learning, such as developing student-centered pedagogy, applying the redesigned assessment and building learner community. Students could settle their learning objectives and activities in collaboration with teachers, and they decide how to show mastery with the help of the right advice. Teachers could provide personalized feedback, coaching, and assistant with adaptive assessment and learning analytics.

- For advancing smart education, it is essential to pay attention to rationales such as cooperation, inclusion, equity, quality, and green sustainability.

- There are six key features of smart education: curriculum and practices improving digital literacy; innovative teaching methods and strategies; assessments supported by AI and big data; personalized and on-demand services for teachers and students provided by the government and enterprises; solutions and policies on open educational resources; new model of educational governance empowered by AI and big data.

The 6th International Conference on Smart Learning Environments

The International Conference on Smart Learning Environments (ICSLE 2022)[4] was jointly held on August 18-20, 2022 at the Hangzhou Normal University (China), The International University of La Rioja (Spain), and Near East University (Cyprus). The theme of the conference is "Intelligent Technology Enhanced Smart Learning". It aims to bring together researchers, practitioners, and policy makers to discuss issues related to the optimization of learning environments to enhance learning. The focus is on the interplay of pedagogy, technology and their fusion towards the advancement of smart learning environments.

Various components of this interplay include but are not limited to:

- Track 1 Pedagogy: learning paradigms, assessment paradigms, social and cultural factors, biases, ethical considerations, policy issues and implications;
- Track 2 Technology: emerging technologies, innovative uses of mature technologies, adoption, usability, standards, and emerging/new technological paradigms (open educational resources, cloud computing, blockchain, artificial intelligence applications in education, etc.);
- Track 3 Integration of pedagogy and technology: transformation of curriculum, transformation of teaching and learning behavior, transformation of administration, best practices of infusion, piloting of new ideas.

4 See http://iasle.net/icsle-2022/

GENERAL CHAIRS

Prof. LIU Dejian
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Prof. Kinshuk
Dean, the College of Information, University of North Texas, USA

Prof. HUANG Ronghuai
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LOCAL CHAIRS

Prof. YANG Junfeng
Hangzhou Normal University, China

Dr. Daniel Burgos
The International University of La Rioja, Spain

Dr. Zehra Altınay
Near East University, Cyprus

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Dr. Ahmed Tlili
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Dr. Maiga Chang
Athabasca University, Canada

Dr. Elvira Popescu
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Smart education is the focus of the national educational informatization at present, the current hot area of education technology research, and an important aspect of the process of education development. The International Conference on Smart Learning Environments (ICSLE) was held for the sixth time, and has been held past in Hong Kong of China (2014), Sinaia of Romania (2015), Tunis of Tunisia (2016), Beijing of China (2018) and Denton of the United States (2019), bringing together international experts in intellectual learning and research, with important international influence.

The conference is chaired by Prof. LIU Dejian (Co-dean of Smart Learning Institute of Beijing Normal University), Prof. Kinshuk (Dean of the College of Information at the University of North Texas), and Prof. HUANG Ronghuai (Co-dean of Smart Learning Institute of Beijing Normal University), and invites scholars from domestic and abroad to participate in the conference to conduct in-depth exchanges and discussions on cutting-edge and hot issues such as artificial intelligence in education, Internet of Things (IoT) and multimodal learning analytics, precise education assessment supported by AI and big data, digital literacy in education in the Intelligent Era, etc.

Criteria of defining "Smart Learning Environments" on ICSLE

Smart learning environments encompass "intelligent tutoring systems (ITSs)", "adaptive learning systems", "technology-enhanced learning", "web-based learning", "mobile learning", "context-aware ubiquitous learning using sensing technologies". They enable learners to access digital resources and interact with learning systems in any place and at any time, and actively provide the necessary learning guidance, hints, supportive tools or learning suggestions to them in the right place, at the right time and in the right form.

Basically, a smart learning system can be perceived as a technology-enhanced learning system that is capable of advising learners to learn in the real-world with access to the digital world resources. Various potential criteria have been identified in the literature for smart learning environments:

- A smart learning environment is context-aware; that is, the learner's situation or the contexts of the real-world environment in which the learner is located are sensed, implying that the system is able to provide learning support based on the learner's online and real-world status.

- A smart learning environment is able to offer instant and adaptive support to learners by immediate analyses of the needs of individual learners from different perspectives (e.g., learning performance, learning behaviors, profiles, personal factors) as well as the online and real-world contexts in which they are situated. Moreover, it can actively provide various personalized support to the learners, including learning guidance, feedback, hints and learning tools, based on their needs.

- A smart learning environment is able to adapt the user interface (i.e., the ways of presenting information) and the subject contents to meet the personal factors (e.g., learning styles and preferences) and learning status (e.g., learning performance) of individual learners. The user interface is not necessarily a conventional computer. Instead, learners can interact with the learning environment via mobile devices (e.g., smartphones or tablet computers), wearable devices (e.g., Google Glass or a digital wristwatch), or even ubiquitous computing systems embedded in everyday objects. Therefore, it is a challenging issue to adapt the user interface to meet the learners' needs in a smart learning environment.

New Ecology of Regional Smart Education

The goal of smart education is to re-construct the smart learning environment, transform traditional teaching and learning methods, and reform the educational system with better learning experience, high content adaptability and high teaching efficiency. The demonstration zones of smart education has carried out bold explorations and beneficial attempts based on local conditions, and has formed some bright spots in terms of environment, model, service and governance. The Ministry of Science and Technology of the People's Republic of China has deployed relevant projects in the field of smart education in key research and development plans.

Report on the Construction Progress of Demonstration Zone of Smart Education

With the aims to implement the strategic action of educational digitalization, further promote the development of smart education, and enhance the dissemination of best practices and experiences of smart education, the Department of Science, Technology and Information of the Ministry of Education of P.R.C takes the lead. The secretariat of the project expert group for the construction of the Demonstration Zone of Smart Education has joined the Educational Informatization Strategy Research Base (Beijing, Central China, Northwest) to launch a campaign to collect outstanding smart education cases. One hundred twenty-three outstanding smart education cases were finalized, including 30 cases on regional construction, 77 cases on school practice, 8 cases on solutions, and 8 cases on research results.

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Mr ZHU Jinggao
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Mr WANG Yi
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Mr XIAO Chunxi
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Mr HANG Ziping
Vice Principal, Zhanggongshan No. 3 Primary School, Bengbu City, Anhui Province, China

Ms PENG Baobei
Principal, Erqiao Middle School in Wuhan, Hubei Province, China

Ms SONG Mengheng
Principal, Qingyuan Primary School, Tianxin District, Changsha, Hunan Province, China

Report on the Construction Progress of Demonstration Zone of Smart Education

The Demonstration Zone of Smart Education [5] is the one of the key tasks of *Education Informatization 2.0 Action Plan*, and it is also an innovative action for the development of regional education informatization. Since the start of the project, the regions have carried out bold explorations and beneficial attempts based on the local conditions, and formed some characteristics and spotlights in terms of environment, model, service and governance. This book summarizes excellent cases and shares experiences/paradigms, providing reference for the development of regional smart education.

In the face of the new situation, new requirements and new tasks of digital transformation and intelligent upgrading of education, the *Demonstration Zone of Smart Education* will seize the current opportunities to form a unique development path of regional smart education, and build new pattern and new ecology of smart education.

This book can be used as a reference for educational policymakers, researchers, principals of primary and secondary schools, teachers, and industry practitioners in the field of smart education.



Mr XU Lin, Director of China Educational Technology, Center for Educational Technology and Resource Development, Ministry of Education, P.R.C (National Center for Educational Technology, NCET), introduced the effect of a “Smart Education of China” Platform on the aspects of the promotion of educational reform, the inclusive sharing of high-quality resources, educating people with home and school collaboration, and the deep integration of information technology and curriculum.

Development of high-quality regional education

Professor WU Di, Executive Deputy Director of Education Informatization Strategic Research Base (Central China) of the Ministry of Education of P.R.C, gave a presentation on “Digital Transformation in Education and the Development of Regional Smart Education”. He emphasized that the development of smart education needs to consolidate the "digital base", and the smart education pilot zone should become the "pioneer" of the digital transformation in education. During the promotion process, we should focus on teaching innovation, education evaluation reform, teacher professional development and education governance optimization. In the future, the amalgamation of differentiated teaching, personalized learning, refined management, data-driven teaching research, and intelligent services will build a better education landscape.

Professor GU Xiaoqing, a member of the Secretariat of the Project Expert Group for Construction of “Demonstration Zone of Smart Education”, focused on the development and future vision of smart education. She explained that the fundamental essence of smart education could be highly summarized as human-machine

5 See http://www.moe.gov.cn/srcsite/A16/s3342/201804/t20180425_334188.html

collaboration, which is embodied in precision, individuality, optimization, collaboration, thinking and creation. The practice of smart education needs to determine the bottom-line principle of human-machine collaboration and follow the learner-centered humanistic learning concept. The future of smart education needs awareness of the future trend, which looks forward to the future and reflects on the present.

Professor XIONG Zhang, Head of the Expert Group on Information Technology Curriculum Standards for Compulsory Education of the Ministry of Education, introduced the "Information Technology Curriculum Standards". He pointed out that we are already in a new social form that is different from the traditional information society - the online society, which puts forward higher requirements for cultivating students' literacy in quality education. Students in the online society must have information awareness and be equipped with computing thinking, digital learning, and innovative ability. They shall also be able to take responsibility for the information society. The discipline logic of the information technology curriculum in compulsory education pursues big concept, theme, experiences and integration, which are interrelated and jointly serves quality education.

Professor Tak-Wai Chan, the Founder of the Global Chinese Conference of Computer in Education (GCCCE), believed education design is to design the future, and we should pay attention to interest-driven education.

Professor J. Michael Spector from the University of North Texas believed educational technology should focus on innovation, integration, and inspiration. The key to the success of the integration of education and technology lies in whether students pay more attention to the learning process and tasks rather than the technology itself.

Practice of Regional Education

Mr LI Yongzhi, Deputy Director of Shanghai Municipal Education Commission, shared the "Strategic Vision and Practical Exploration of Digital Transformation in Education". He introduced Shanghai's digital transformation strategy from five aspects:

- improving the digital literacy and skills of the whole society;
- innovating a high-quality personalized lifelong learning system;
- deepening the reform of education and teaching;
- systematically building digital educational resources; and
- promoting the reengineering of education management and service process.

He further demonstrated the practice and exploration of Shanghai's digital transformation in education from the perspectives of data governance, base connection, ecological cultivation, service purchase, and educating people.

Ms XIONG Qiuju, Director of the Education Bureau of Changning district in Shanghai, pointed out three dilemmas of regional education: uneven resources, insufficient teaching, and lack of operation and maintenance. The path of digital transformation at Changning district will be based on the digital base and build regional smart education with characteristics of standardization and personalization.

Mr HE Meilong, Director of the Education Bureau of Minhang district in Shanghai, focused on the construction of a digital smart

education platform, big data-driven teaching and learning, digital transformation for teachers and digital education public services. He also described the specific practice of how digital transformation promotes the transformation of smart education in the Minhang district.

Mr ZHANG Xianguo, Director of the Information Technology Department of the Beijing Municipal Education Commission, shared the achievements of Beijing's practice of digital transformation in education, including effectively guaranteeing online teaching, innovating education and teaching approaches, supporting individualized and independent learning, exploring multiple educational evaluation methods, promoting teacher professional development, and planning intelligent education models. Aligning the path of digital transformation in education – "one base", "six scenes", and "three spaces" – Beijing will initially form a new future-oriented education ecology by 2025.

Mr GAO Wei, Director of the Education Commission of Dongcheng District in Beijing, introduced the progress of smart education construction in Dongcheng District. The district has formed a unique development path around the "1+7+N" smart education service system. At present, "1" "data brain" has begun to take shape, "7" projects have been solidly advanced, and several ("N") future schools are in exploration.

Mr QIU Chengyu, Deputy Director of Shenzhen Education Bureau, introduced the development of smart education in Shenzhen. Shenzhen has adopted the systematic top-level design of "integrated empowerment, four innovations and six intelligence, and eight scenarios" and makes the achievements in smart governance, teaching reform, resource construction, talent team building, and mechanism innovation. It realizes the goal of "improving quality and innovation through digital transformation and reducing the burden and increasing efficiency through intelligent upgrade".

Mr SHENG Liang, Director of the Education Bureau at Bengbu, shared the promotion of education informatization mechanism based on the collaboration of government, enterprise, school, and research. He introduced the practices in the areas of organizational construction, teacher training, subject research and education governance, which benefits the co-construction and co-sharing of resources, the in-depth promotion of application, the innovation of teaching mode and the construction of teacher teams.

Mr ZHU Jinggao, Deputy Director of the Education Bureau of Wenzhou, introduced the progress of smart education construction in Wenzhou. The city has built a "1+3+X" construction system of "digital brain", formed an education data center, established three digital service centers, supported multiple educational application scenarios, and realized data-enabled education.

Mr WANG Yi, Director of the Education Bureau of Wuhou district in Chengdu, introduced the practical exploration of Wuhou's smart education. Wuhou district mainly focuses on three areas: teaching, service and governance, and three tasks: building new ecology of smart education, new forms of educational services and intelligent governance, with an aim to provide a suitable education for students.

Best practices of smart education in schools

Ms DOU Guimei, Principal of Tsinghua University Primary School, introduced the situation of teachers and students in both Tsinghua

University Primary School and rural areas taking “the same class”, as well as the symbiosis model of high-quality resources based on the needs of teachers and students in rural areas.

Mr MA Long, Director of the Sports Arts Training Department of the Institute of Educational Sciences, introduced how AI is applied for data collection and application of primary school sports load and how it promotes the effective development of sports education at Dongcheng schools.

Ms XU Hongyan, Principal of the Happiness Primary School in Shaya County of Xinjiang Uygur autonomous region, is an educator who aided Xinjiang. She shared her experiences of leading a group of young teachers to go deep into the frontier, carrying out group-style teaching and research, and leading the change in local education and teaching mode in the past two years.

Ms ZHANG Xiaoyan, Vice Principal of Yongji Chengxi Middle School in Yuncheng city, shared a case on how online learning space broadens the growth path of left-behind children.

Ms GONG Mingxing, a senior teacher at Donghu High School in Yiling District in Hubei Province, introduced the achievements of the school's practice of labor education based on the smart education platform.

Mr HANG Ziping, Vice Principal of the Zhanggongshan No. 3 Primary School at Bengbu City, shared the school's exploration and innovation of online and offline teaching models, which was based on the “Smart Education of China” Platform (https://www.zxx.edu.cn/). It effectively helped to maintain continuous learning during COVID-19 outbreak.

Ms PENG Baobei, Principal of Erqiao Middle School in Wuhan City, presented the measures, effects and prospects of using the virtual experimental teaching system and the Wuhan Education Cloud to carry out normalized experimental teaching.

Ms SONG Mengheng, Principal of Qingyuan Primary School at Tianxin District in Changsha City, shared a school practice case of promoting the innovative development of primary schools' thinking and political education with "Smart Thinking and Political Activity Hall".

Smart Education Solutions for Challenges of Education

Mr XIAO Chunxi, General Manager of Industry BG Technical Department of H3C, introduced the company's practice in promoting smart education through ideological and political education, high-quality "double reduction – reducing students’ homework and off-campus training burden", and education management. **Mr ZHOU Jiafeng**, Vice President of iFLYTEK, shared the practical case of how artificial intelligence empowers regional large-scale individualized teaching. **Mr JIN Xin**, General Manager of the Smart Education Division of Lenovo's major customer business group in China, focused on teacher professional growth and explained Lenovo's technical solutions to break through the difficulties of teaching and research.

New Ecology of Regional Smart Education
Key takeaways

- When building regional smart education ecology, four focus points are essential for consideration, namely, innovative teaching, assessment transformation, teacher professional development, and governance optimization.
- Establishing high-quality education system shall first of all ensure the all-round, healthy and happy growth of students, and design a more flexible school system.
- One of the key aspects of building the new ecology of regional smart education is to continuously upgrade the cloud platform and improve the resource integration, realizing the collection, classification and search for high-quality educational resource.
- The introduction of AI-driven systems in the regional schools provides assignment analysis from multiple levels and perspectives, which enhances teachers' teaching coordination ability, helps teachers adjust teaching methods, optimizes school-based question banks, and promotes the overall teaching effectiveness of schools.
- Achieving the digital transformation in regional schools shall address the data isolation problem. Specifically, it includes the continuous use of existing data, the integration and application of inter-school data, and the sharing of data between schools.
- The promotion of regional informatization shall give full play to the advantages of the government, enterprises, schools, and research institutions. The cooperation among these four entities and clarification of their individual responsibilities or functions can help to formulate effective work promotion plans and managerial work mechanisms.

Student Forum on Learning Crisis and Futures of Education

Based on the actual situation of their countries and regions and combined with their own experiences, 15 outstanding university student representatives from China, Malaysia, Bangladesh, Serbia, South Africa, Tunisia, Uganda, and Nigeria shared their understanding of the learning crisis and their expectations for the futures of education from four dimensions: learning environment reform, learning method innovation, rural student training and inclusive education realization.

Transforming Learning Environments to Solve the Learning Crisis

It is one of the learning crises in the world that learning in schools may not necessarily acquire the required knowledge and skills. The learning environment needs to be developed, and the education ecosystem, school form and teaching methods need to be developed accordingly. Governments, schools, families and the whole society need to work together to promote the digital transformation of education to help students acquire the abilities needed in the fourth industrial revolution.

Ms LIU Yufei from Beijing Normal University held that it was a prominent learning crisis that students' learning achievements do not match the future social needs. Moreover, teaching cannot support learners' development and well-being in the future, which requires the joint efforts of the school and the whole society to resolve. She mentioned under the guidance of the concept of Outcomes-Based Education (OBE), we could systematically think and redesign the learning environment from the perspectives of teaching objectives, teaching contents and

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Mr BAO Haogang
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SPEAKERS

Mr SONG Weizu
Founder, Beijing Design Society, China

Ms Tatiana Shutova
Programme Specialist, UNESCO IITE

Prof. Danimir Mandic
Dean, Teacher Education Faculty, University of Belgrade, Serbia

Ms NI Jiaqi
Deputy Secretary, Beijing Normal University Committee of Communist Youth League of China

STUDENT SPEAKERS

Transforming Learning Environments to Solve the Learning Crisis	Developing Learning Methods to Solve the Learning Crisis	Developing Competencies for Sustainable Development among Rural Students	Integrating Resources to Achieve Inclusive Education
Ms LIU Yufei Graduate student, School of Foreign Languages and Literature, Beijing Normal University, China	**Ms ZHANG Wenjie** Graduate student, Educational Psychology, The University of Hong Kong, China	**Mr ZHU Xuan** Undergraduate student, Art Center College of Design, USA	**Mr CHEN Xing'an** Undergraduate student in sociology, Diablo Valley College, USA
Ms Jelica Ristić PhD candidate, Teacher Education Faculty of the University of Belgrade, Serbia	**Mr Oluwatayo Israel Olasunkanmi** Post-doctorate, Chongqing University, China	**Mr Muganga Allan** Graduate student, Mathematics education, Southwest University, China	**Ms Har Wee Ai** Undergraduate student, Faculty of Education, Beijing Normal University, China
Ms Salwa Mrayhi PhD candidate, Virtual University of Tunis	**Ms MEI Zixuan** Graduate student, College of Education, Capital Normal University, China	**Mr Shrorif Mollah** PhD candidate, Faculty of Education, Beijing Normal University, China	**Ms Khutso Tania Segooa** Graduate student in Economics, Fordham University, USA
Mr YANG Liu Undergraduate student, School of Arts and Communication, Beijing Normal University, China	**Ms YAO Jia** Undergraduate graduate, School of Government Management, Beijing Normal University, China	**Mr LIU Jiahao** PhD candidate, Faculty of Education, Beijing Normal University, China	

teaching evaluation, so as to promote students' flexible, active and spontaneous learning, and thus improve their comprehensive ability required in the future.

Ms Jelica Ristić from the University of Belgrade recalled that during the COVID-19 pandemic, students' obstacles to self-identity and teachers and students' inability to adapt to the rapidly developing digital learning environment are the crises that we must pay attention to. A blended learning environment and teacher training services are one of the solutions to overcome the crisis. The blended learning environment carried out by the University of Belgrade in the form of Flipped Class Model had proved its important role in improving the learning experience, enhancing the interaction between teachers and students, and improving the overall learning. Based on the Edmodo learning platform, she and her team designed a Metaverse Application Skills Improvement Program to help teachers conduct daily teaching, online teaching and B-teaching in the metaverse.

Ms Salwa Mrayhi from Virtual University of Tunisia held that it was a great crisis that teachers and students cannot complete effective learning in the digital learning environment, and that governments and schools need to implement the digital learning environment strategy. She proposed to provide teachers with rich tools and necessary training. Her team designed a system framework of massive open online courses (MOOC), aiming to provide personalized learning and support for students to improve their learning efficiency.

Mr YANG Liu from Beijing Normal University emphasized that it was a major crisis that the traditional classroom is not suitable for students' equal exchange and effective learning, and the widespread application of new technologies may cause privacy and ethics problems. He said that school should be a friendly, open, free, inclusive, fair, safe and healthy place. The application of intelligent technology must be people-centered and it is essential to build a student-centered learning space. He worked with his team to design an immersive future classroom based on an intelligent interactive system (Illusion), which provides space for equal communication and cooperation between special children and ordinary children, so as to achieve educational equity.

Developing Learning Methods to Solve the Learning Crisis

Education is at a critical stage of digital transformation, and technology-based learning methods emerge in an endless stream. However, “using technology just for the sake of technology” has brought new learning crises. The innovation of learning methods should help students improve their interest in learning, involve in the process of learning, and cultivate them to shape their future “transformative attainment”. This is about creating new values, assuming responsibilities, mediating pressure and coping with difficulties, all from the perspective of promoting people's all-round development.

Ms ZHANG Wenjie from the University of Hong Kong mentioned that students' poor learning skills and poor learning quality were a major crisis at present, and students' skills for the 21st century should be improved through online education. She said that the frequency and level of students' classroom questioning could reflect their cognitive level. Therefore, she worked with her team members to design a software that automatically analyzes students' classroom questioning, which can provide visual analysis charts and feedback reports. Teachers can provide guidance according to the data, so that students can be good at asking questions and improve their meta-cognitive ability.

Mr Oluwatayo Israel Olasunkanmi from Chongqing University pointed out that the uneven quality of education in various countries in the world was one of the current learning crises. In particular, many school-age children in low-income countries do not have the basic skills of reading and calculating numbers. Moreover, teachers cannot get the support and development they deserve. He believed that it was necessary to strengthen global cooperation, adopt digital learning to promote education equity, and train 21st-century skills for learners in low-income countries.

Ms MEI Zixuan from Capital Normal University emphasized that students' failure to develop the transferable ability and general attainment was a major learning crisis, which would hinder students from integrating into the future society. She said that the direction of learning method innovation should be “making the world a classroom”. The situational learning method can create real problem situations, help students participate in the learning process, solve real problems through interdisciplinary knowledge, and cultivate students' abilities to shape the future.

Ms YAO Jia from Beijing Normal University highlighted that the insufficient use of

technology, lack of qualified teachers and insufficient access to high-quality education were the three major learning crises in China, and COVID-19 had brought challenges to educators. She believed that China's experience during the COVID-19 was worth promoting, such as building a reliable network infrastructure, using convenient learning tools and platforms, and providing appropriate digital learning resources. We should jointly build a community with a shared future in cyberspace and bridge the “digital divide” to cope with today's learning crises.

Developing Competencies for Sustainable Development among Rural Students

Rural students lack sufficient resources during their study and life in general, and the learning crisis caused by dropouts, absenteeism and school-weariness make it worse. In the face of the complex and changeable future society, it is necessary to strengthen the close integration of education with rural economic development and social environment, cultivate students' sustainable development ability, and make full preparations for the effective integration of rural students and economic society.

Mr ZHU Xuan from the ArtCenter College of Design held that the lack of design thinking and innovation ability were major issues of the learning crisis faced by rural students. He mentioned that it was very important to make rational use of the natural resources in rural areas to create conditions for rural students. He worked with his team to design a low-cost rural students' design thinking educational project. Through three different spaces, students are allowed to operate experiments to design and create works based on local resources, which helps to cultivate students' curiosity, observation ability and practical ability.

Mr Muganga Allan from Southwest University mentioned that the imbalance in education between urban and rural areas, and the serious shortage of teachers were the common challenges of the learning crises in Uganda. Some rural primary schools have only one teacher to teach all courses, and even many students have classes under trees. When it rains, the courses will be canceled. He held that rural areas need basic facilities and Internet access, as well as enough teachers to ensure students receive formal education. All countries in the world need to work together to achieve the goal of “ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all”.

Mr Shorif Mollah from Beijing Normal University mentioned that the lack of high-quality learning resources was a learning crisis in Bangladesh and other developing countries. Especially in rural areas, teaching is basically a teacher's oral and dictation process, which cannot cultivate students' sustainable development ability. He introduced an Open
Educational Resources (OER) research project, and emphasized the importance of OER in achieving quality education for all and promoting the sharing of education resources.

Mr LIU Jiahao from Beijing Normal University pointed out that it was the main crisis in education that teachers' application of technology was overloaded, and the effectiveness of technology application in education was questioned. He held that in the process of promoting sustainable development education in rural areas, we should not overemphasize technology. Instead, we should guide teachers to master basic technologies and apply them rationally and help students learn to deal with the relationship between themselves and the society, the world, the nature and ultimately make contributions to the overall social progress and development.

Integrating Resources to Achieve Inclusive Education

There are still several problems in the world that children with special needs face. Many do not have access to schools. Many girls are out of school due to gender discrimination Vulnerable groups do not receive high-quality education. During the COVID-19, the response measures of various countries did not take children with special needs into account. As a result, their basic learning and emotional needs could not be met. We need to make collective efforts and integrate various resources to ensure everyone's right to education.

Mr CHEN Xing'an from the Diablo Valley College held that the lack of barrier-free learning resources and fair employment opportunities for disabled people was one of the crises in achieving inclusive education. As a visually impaired person, he was considered unable to enter a university or have a good job from an early age. He faced many restrictions in primary and middle school stages. He proposed three solutions—community support, online learning programs and public-private partnerships programs to promote the formal learning and career development of the disabled.

Ms Har Wee Ai from Beijing Normal University mentioned that the basic health services and education services in Malaysia did not include the disabled, and this exclusion and discrimination had brought a great crisis. She held that people should have a common understanding of inclusion and diversity. The United Nations International Children's Emergency Fund (UNICEF) in Malaysia has launched an inclusive playground for disabled children, which is a very good way to achieve emotional education. She worked with her team to design a metaverse education game called “Mind Forest Pro” for students aged 4-12 to promote the social and emotional learning of autistic children.

Ms Khutso Tania Segooa from Fordham University highlighted that the students in special schools in South Africa had a serious lack of learning and did not have the basic reading and writing skills required for employment, which was a major crisis. She held that the disabled should be included in mainstream schools to study and communicate with the non-disabled. She proposed an APP with visual elements to support the understanding, expression and communication of speech-impaired children, and she hopes to use the APP as a bridge for interaction between speech-impaired children and teachers as well as classmates.

Mr SONG Weizu, Founder of Beijing Design Society, pointed out there were still some problems in education in today's world, such as dropouts, lack of teachers, difficulty in going to school and many more. The learning crisiscaused by primitive educational knowledge and rigid teaching methods needs to be paid attention to. With the advent of the new era of innovation-driven development, the knowledge structure and knowledge learning content have developed in the direction of art, science and technology, and that they are complementing and completing each other. It has become a new trend to pay equal attention to knowledge and skills, interdisciplinary learning, and the unification of brains and hands.

On behalf of UNESCO IITE, Ms **Tatiana Shutova**, the Programme Specialist, expressed a warm congratulation to Beijing Normal University’s 120th anniversary. She pointed out UNECO IITE and BNU had been cooperating in many projects, especially the concluded 5th Global Competition on Design for Future Education, in which a number of unique university students' projects and primary and secondary school teachers' cases have been produced, and some of them have been included in the UNESCO E-Library For Teachers. Built by UNESCO IITE and NetDragon, E-Library For Teachers has effectively solved the

problems of teachers' lack of professional knowledge and rigid teaching methods, helped teachers master new technologies, improved their teaching ability, and provided effective solutions for education and teaching.

Professor Danimir Mandic, Dean of Teacher Education Faculty at the University of Belgrade in Serbia, mentioned that in response to the learning crisis, future education should make full use of the advantages of AI technology to innovate teaching methods and improve teachers' ability. On one hand, it can analyze and reorganize the knowledge structure to improve students' learning motivation; on the other hand, through training, seminars and other forms, it can help teachers master new technologies and improve their teaching ability.

Ms NI Jiaqi, Deputy Secretary of Beijing Normal University Committee of Communist Youth League of China, argued the learning crisis was complex. Some people do not have the conditions for learning; some have good conditions but are not interested in learning; and some are interested in learning but lack effective learning methods. These problems are closely related to the futures of education and the development of human society. Education is an effective way to eliminate poverty and promote social progress. It plays an important role in building a 'Community with a Shared Future for Mankind'. University students are the backbone of future social development. They have knowledge, dreams and a sense of social responsibility. In his congratulatory letter to the World Youth Development Forum, President XI Jinping pointed out "the youth of all countries should carry forward the shared values of humanity's peace, development, equity, justice, democracy and freedom; to promote the global development initiative with practical actions; to help implement the UN 2030 Agenda for Sustainable Development; and to jointly write a new chapter in the era of solidarity and cooperation among the world's youth". Ms NI Jiaqi looks forward to building a platform through the Forum so that university students from all over the world can perceive the crisis, exchange and learn from each other, and achieve common development.

Student Forum on Learning Crisis and Futures of Education
Key takeaways

Future Education Envisioned by International University Students

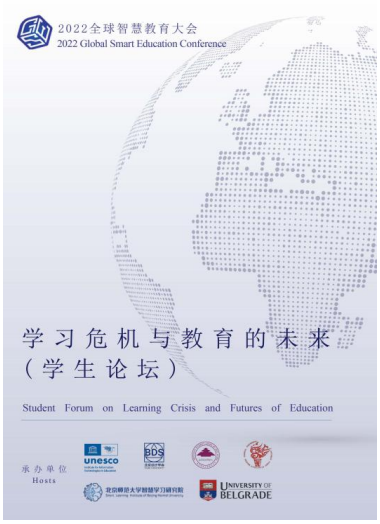
University students have their own imaginations about futures of education. They hope to achieve high-quality, inclusive and equitable education through innovative technology integration, ubiquitous learning, resource sharing, intelligent learning environment and effective teaching methods, so as to promote everyone's ability development and well-being and the sustainable progress of a harmonious society. The construction of a 'Community with a Shared Future for Mankind' is a key phrase repeatedly mentioned.

- Students hope that technology can play a more important role in education.
  - Mr YANG Liu summarized the characteristics of future education with four keywords: ubiquitous, personalized, predictable, and dynamic.
  - Mr Muganga Allan hopes that technology in the future can be better integrated with education, and teachers and students can easily use technology for personalized learning, so as to truly cultivate students' basic skills for the 21st century.

- Mr LIU Jiahao hopes that with the support of technology, the future learning space will be everywhere and interconnected, with seamless connections between school, family and society, and that informal learning and formal learning will be organically combined.

- Students hope that future education will be more inclusive.
  - Mr CHEN Xing'an expects that future education will enable every disabled people to have access to high-quality learning resources and employment opportunities.
  - Ms Khutso Tania Segooa hopes that the restriction of disabled children in education will be greatly reduced in the future, and that they can learn various useful skills in school to have better opportunities in the society.
  - Ms Har Wee Ai held that “promoting learning through design” can help us re-envision the world, and all professions can participate in creating inclusive infrastructures, products and services to create a quality life for mankind.
  - Mr Shrorif Mollah hopes future education to be more inclusive, global and practical.

- Students hope that future education will be more equitable.
  - Ms LIU Yufei expects that in the future, everyone in the world can learn more flexibly and independently, and enjoy high-quality educational resources and educational fairness.
  - Ms Salwa Mrayhi hopes that future education will enable students to enjoy the learning process, realize personalized learning and lifelong learning, and transform the world into a more equitable and sustainable future.
  - Ms MEI Zixuan has a vision that future education will be more fair and equitable, so that everyone can enjoy a decent life.



Report on Student Forum on Learning Crisis and Futures of Education[6]

6 See http://sli.bnu.edu.cn/uploads/soft/220921/1_1656079011.pdf

Teacher Forum on Technology Empowered Teaching Innovation

Education is eminently a human-centric endeavor, not a technology centric solution. As they have humanistic characteristics, teachers could make new contributions to the development of fairer and higher quality education through rationally using technologies. This forum invited teachers, policy makers and researchers from domestic and overseas universities, vocational colleges, primary and secondary schools, kindergartens to discuss and exchange new mechanisms, new ideas and new methods of technology-supported teaching.

Professor ZHENG Qinhua from Beijing Normal University pointed out the major issues in this intelligent era featured by "human-machine collaboration, cross-discipline integration, co-creation and sharing". That is to

- preserve the value of human beings;
- carry forward the humanistic spirit of harmony and difference, freedom and openness, benevolence and tolerance; and
- use information technology to serve the common interests of mankind as well as the innovative development of education.

The transformation of the learning space

Professor Jim Slotta from the University of Toronto emphasized active learning classrooms. He shared several real cases of smart classrooms like WISE (https://wise.scnu.edu.cn) and Tangible and Embodied Learning Lab, and stressed new patterns of student-teacher interaction in the

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SPEAKERS

Prof. ZHENG Qinhua
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Ms TANG Shaobing
Vice Dean, Institute of Educational Development, Huadu District, Guangzhou, Guangdong Province, China

Prof. Jim Slotta
University of Toronto, Canada

Mr ZHANG Xiaohu
Associate Professor, Xi'an Eurasia University, China

Prof. Georgeta Panisoara
Psychology and Habilitation in Educational Sciences, Bucharest University, Romania

Mr HE Qigang
Director, Supervision Office of the Education Bureau of Tianyuan District, Zhuzhou City, Hunan Province, China

Ms DUAN Yanqing
Yuncheng City Education Bureau of Shanxi Province, China

Ms ZOU Xianlian
Principal, Xingyuan Primary School in Liangjiang New District, Chongqing, China

Ms Li Ahui
Principal, Kaiyue Kindergarten, Xiaoshan District, Hangzhou, Zhejiang province, China

Dr. Jördis Weilandt
Assistant Program Manager, Rebus Community, Canada

Mr FENG Hongke
Beijing No. 20 Middle School, China

Ms LI Yan
Principal, Shenyang Railway Experimental Primary School, China

Mr LIU Chao
Academic Affairs Director of Zhengtai Bowen School, Xiangcheng City, Henan Province, China

Ms WU Dingcui
Principal, Bagu Primary School in Lugu Town, Mianning County, Sichuan Province, China

Prof. Ramesh C. Sharma
Ambedkar University Delhi, India

Prof. Mauricio Xavier Prado Ortega
Technical University of Machala, Ecuador

Ms ZHAO Jing
PhD candidate, Tongji University, China

Mr FAN Yizhou
Research Associate, School of Informatics, the University of Edinburgh, Britain

21st-century classrooms. For example, he suggested that teachers shall create small-group discussions instead of giving lectures while students could use phones or computers as learning resources. He also shed light on the design of classroom space for active learning.

Ms ZOU Xianlian, Principal of Xingyuan Primary School in Chongqing, China, shared her views on the new exploration of digital transformation in primary classrooms. She elaborated on key common factors of different classroom models, new forms, features, application logic, platform support and exploration results of “multi-course mixing”. She believed it would help to explore a new paradigm of learning and promote the digital transformation in education.

Mr FENG Hongke from Beijing No. 20 Middle School gave a presentation on “Empirical Research on Intelligent Teaching Behaviors in Real Classroom Scenarios”. He suggested that AI-driven data collection could help to relieve teachers’ burden and enhance the effectiveness of teaching practice.

Technology-empowered teaching innovation

Ms TANG Shaobing, Vice Dean of the Institute of Educational Development in Guangzhou, China, delivered a speech on “Regional Intelligence Teaching and Research Empowered by Artificial Intelligence”. She pointed out 6 key factors of regional intelligence teaching and research: teacher, classroom, platform, technology, real-world problems, and methods. She noted that the underpinning theory is a data-supported regional collaboration model; in other words, it is a closed loop based on problem-driven classrooms, technology empowerment, platform support, and collaborative innovation.

Ms LI Yan, Principal of Shenyang Railway Experimental primary school, focused on“Information technology energizes the education scene and upgrades the dimension of

school space ecology". She introduced the school's development of "cloud research, cloud teaching, and cloud management", which helped build a smart campus where both students and teachers benefited.

Professor Mauricio Xavier Prado Ortega from the Technical University of Machala delivered a speech on "Learning analytics in higher education through the application of collaborative tools". Through this research, he found that the application of learning analytics could help to monitor and evaluate students' learning in a real-time manner; and collaborative tools like Google Analytics could help to measure students' progress and level of connectivity in synchronous learning.

Ms WU Dingcui, Principal of Bagu Primary School in Sichuan Province, China, focused on the application and practice of VR in education in minority areas. She believed teachers in rural primary schools in the ethnic minority area should not only strengthen the cultivation of cultural quality but also apply modern educational technology to classroom teaching. Teachers should also utilize the advantages of modern educational technology to expand children's horizons, and improve children's cognitive ability and thinking abilities.

Dr. Jördis Weilandt, Assistant Program Manager of Rebus Community, focused on compassionate and inclusive student learning in higher education. She shared the OER publishing project called "Textbook Success Program", which guides participants to move smoothly through the steps of publishing open teaching materials. She also suggested 3 ways to design for inclusion and equity: technical, content, and human accessibility.

Mr HE Qigang, Director of the Supervision Office of the Education Bureau of Tianyuan District in Hunan province, China, introduced the concept of "Educational Micro-Universe", which he believed will address some of the current challenges facing the metaverse application in education.

Ms ZHAO Jing from Tongji University talked about the Metaverse Game from a novel perspective of Lao Tzu's Cosmology. She explained the thinking model of Lao Tzu's cosmology, based on which the possibilities of applying it in the field of education in the metaverse were discussed.

Mr ZHANG Xiaohu, Associate Professor from Xi'an Eurasia University, focused on the "Construction and Practice of Promoting Deep learning of OMO Integrated Teaching During Epidemic Situations". He shared his research paper results on the teaching practice of OMO in multi-scenario, which makes the online and offline learning more seamless.

Ms DUAN Yanqing from Yuncheng City Education Bureau of Shanxi Province, China, highlighted professional development of regional maker teachers. She noted that the curriculum system should be established based on local conditions, and schools should provide organizational, financial, institutional, and environmental support.

Professor Ramesh Sharma from Ambedkar University Delhi believed the 5th education revolution would be driven by the desire to achieve sustainable development goals as well as the science of learning. In a longer-living and aging society, everybody would have access to secondary careers and lifelong learning.

Building 21st century competencies for intelligent era

Ms Georgeta Panisoara, Associate Professor from Bucharest University in Romania, shared the research outcomes of her paper - Teaching

the Next Generation (Generation Z and Alpha) in Digital Society. She talked about digital pedagogy from the aspects of teacher adaptation, children's skill, digital textbooks, VR, platforms, etc. In her view, children shall be equipped with creative skills, communicative skills, and the ability to use technologies to prepare them for the future. During this process, digital resources and technologies like VR could help to build such competencies.

Ms LI Ahui, Principal of Kaiyue Kindergarten in Hangzhou, China, highlighted the integrated design and exploration of digital intelligence in kindergarten. She talked about the need for digital and intelligent development in preschool education and practices on kindergarten management, learning space, early childhood development, and curriculum construction. She believed digital intelligence would help to prepare children for the future, including the adaptation of pedagogic approaches and learning styles and optimization of curriculum resources.

Mr LIU Chao, Academic Affairs Director of Zhengtai Bowen School in Henan Province, China, focused on the Challenges and Countermeasures of Rural Primary and Secondary School Teachers' Professional Development. He suggested the pathway for fostering teachers' smart teaching ability is to study famous educators' works, learn how to use digital tools, actively apply teaching practice and reflect on classroom performance, follow the latest journal articles and accumulate professional knowledge.

Mr FAN Yizhou, a researcher from the University of Edinburgh, shared his research findings on self-regulated learning, including the measurement, analysis, and intervention of learners' self-regulation process. He noted that the bottom line is understanding the technology, students, and the teaching and learning process.

Teacher Forum on Technology Empowered Teaching Innovation
Key takeaways

- The personal development of teachers requires a learning community that can inspire and complement each other, and this cooperative group can prompt teachers to generate new understandings and rise to new levels.

- The development of digital teaching materials is the basis for leveraging the digital transformation of classroom teaching and realizing the sharing of high-quality educational resources. The key point of developing digital teaching materials is to design interactive and editing tools, build knowledge graphs and platforms, and explore new models of digital teaching based on various application scenarios.

- The 21st century classroom will show new patterns of student-teacher interactions empowered by intelligent technologies. Teachers could be able to get off the stage, stop lecturing, and work with small groups of students; as a result, teachers would have clearer understanding of what their students are thinking and how they make sense of the ideas.

- Teachers can match different class types and effectively transformed the teaching and studying ways according to various situations like learning base, disciplinary features and lesson content to reach high-quality classes.

- As primary school teachers in rural ethnic minority areas, we should be more adapt at applying various advanced teaching methods like VR to make the process of imparting knowledge more direct, so that students can more intuitively feel the knowledge they want to master, and learn the knowledge they want to learn in a relaxed and pleasant environment.

Smart Village and Transformation of Rural Education

More than 3.4 billion people in the world, or more than 43% of the world's population, and about 80% of the poor still live in rural areas. In the process of realizing the transformation and modernization of education, making up for the shortcomings of rural education is a major issue and challenge facing all countries. This forum shared the experiences or cases of how education promotes rural development and transformation in different countries and regions, discussed educational solutions for smart village and rural sustainable development, and contributed to the realization of rural revitalization strategy and the United Nations Sustainable Development Goals.

Responding to the global education crisis through joint efforts

Mr WANG Lei, Deputy Director of the Office of International Exchange and Cooperation, Beijing Normal University, delivered an opening address at the forum. He briefed a speech about the negative effects that COVID imposed on the global education system, highlighting that women and children were particularly vulnerable. "Against the challenges of the global education crisis and learning loss, smart education will become an important breakthrough. Smart education is the target form of digital transformation of education." Wang noted. He also stressed his appreciation to all co-organizers and guests on behalf of Beijing Normal University, expressing the organization's wish to cope with the global education crisis and strive for the SDGs together with its global partners.

MODERATOR

Prof. ZENG Xiaodong
Executive Director, UNESCO INRULED

Dr. ZHAO Yuchi
Deputy Director, UNESCO INRULED

SPEAKERS

Prof. WANG Lei
Deputy Director, Office of International Exchange and Cooperation, Beijing Normal University, China

Dr. Ethel Agnes P Valenzuela
Director, SEAMEO Secretariat

Dr. Faiz H. Shah
Director, Yunus Center AIT, Thailand

Prof. Muhammad Yunus
Founder of Grameen Bank in Bangladesh, Nobel Laureate, Chairman of Yunus Center at AIT

Prof. WANG Jixin
Faculty of Artificial Intelligence in Education, Central China Normal University, China

Dr. Roger Y. Chao Jr.
Assistant Director/Head, Education, Youth and Sports Division, the Association of Southeast Asian Nations (ASEAN) Secretariat

Dr. HAN Wei
Executive Deputy Director, International Centre for Higher Education Innovation under the auspices of UNESCO (UNESCO-ICHEI)

Dr. Janaka Jayalath
Deputy Director General, Tertiary and Vocational Education Commission, Sri Lanka

Dr. Glenn B Gregorio
Director, SEAMEO Regional Centre for Graduate Study and Research in Agriculture, Philippines

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Digital Education in K-12 Schools in China: A Comparative Case Study of Rural and Urban Areas

Prof. ZENG Xiaodong
Executive Director, UNESCO INRULED

Dr. LI Baoping
Associate Professor, Deputy Dean of Institute of Rural Education and Rural Development, Beijing Normal University, China

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Dr. Pietro Borsano
Executive Deputy Director, School of Integrated Innovation, Chulalongkorn University, Thailand

Mr QI Zhiwen
Dean, Department of Higher and Vocational Education, Gansu Institute for Educational Research, China

Prof. Moshed M Ahmad
Head, Department of Development and Sustainability at AIT, Thailand

Prof. Kiichi Oyasu
Director, Education Cooperation Department, Asia-Pacific Cultural Centre for UNESCO, Japan

Dr. Nguyen The Manh
Rice Program Manager, Rikolto in Vietnam and Rice Programme Director, Rikolto in Southeast Asia, Vietnam

Mr Emmanuel Krou N'Guessan
President, NGO GA-TIC, 2021 Laureate of the UNESCO Confucius Prize for Literacy, Côte d'Ivoire

Dr. Shoukat Ali
Associate Professor, Institute of Agricultural Extension Education and Rural Development, University of Agriculture, Pakistan

Mr Asrul Sidiq
Researcher, International Centre for Aceh and Indian Ocean Studies (ICAIOS), Indonesia

Mr Phonedalom Bounkham
Director, Permanent Secretary Office, Ministry of Foreign Affairs, Lao PDR

Dr. Ethel Agnes P Valenzuela, Director of SEAMEO Secretariat, expressed her thanks to the invitation from Beijing Normal University and introduced the motivation and missions of SEAMEO. She stressed the COVID-19 was also an education crisis. A series of strategies adopted by the organization, combining ICT and updating pedagogy, successfully helped the region downsize the aftermaths of lockdowns in terms of education. Finally, she urged that it was the

time for achieving educational transformation.

Dr. Faiz Shah, Director of Yunus Center AIT, Thailand, stressed the significance of AI and ICT in education because they make education "less expensive" and "ubiquitous." With some examples, he demonstrated the transformational role of education with the help of technology, who shared the same idea with Professor Yunus. He introduced some work that AIT Yunus center has been doing to prompt digital inclusion and digital transformation. Through videos, he shared with the guests Professor Yunus's interpretation of three-zero world and three-zero club.

Professor Muhammad Yunus, Founder of Grameen Bank of Bangladesh and the laureate of Nobel, highlighted the significance of the right education and the right thinking for building the future world. Combined with his experience of founding Grameen Bank, he emphasized fostering creative thinking and ensuring the well-being of students, and proposed the wish of three-zero world — "zero emission, zero poverty and zero unemployment", and introduced three-zero club, aiming to build a platform for people to discuss about creating a three-zero world.

Building smart education environment in rural areas

Professor WANG Jixin from Central China Normal University introduced the findings of his team's experiment of augmented interactive teaching reform, which aimed to improve the teaching quality of rural schools.

Dr. Roger Y. Chao Jr., Assistant Director/Head of Education, Youth and Sports at the ASEAN Secretariat, reviewed the history and a series of documents and initiatives issued by ASEAN on promoting a society of life-long learning.

Dr. HAN Wei, Executive Deputy Director of UNESCO-ICHEI, talked about the Practices and Experience of Building a Global Community of Higher Education Digital Transformation in three dimensions: theoretical research on education; a platform of extensive consultation, joint contribution and shared benefits; and international and interdisciplinary collaboration.

Dr. Janaka Jayalath, Deputy Director general of Tertiary and Vocational Education Commission in Sri Lanka, introduced the project “Skill Passport” to the audience. As an innovative practice integrating technologies, the project aimed to improve the quality of tertiary and vocational education in Sri Lanka.

Dr. Glenn B. Gregorio, Director of the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEAMEO-SEARCA) in the Philippines, gave a speech about the six key areas for R&D to accelerate the transformation of the agriculture sector and food security in a post-COVID period.

Digital Education in K-12 Schools between Rural and Urban Areas in China

A research outcome - Digital Education in K-12 Schools in China: A Comparative Case Study of Rural and Urban Areas (*School Case Study Report*) - were jointly released by **Dr. LI Baoping**, Deputy Dean of the Institute of Rural Education and Rural Development, Beijing Normal University, and **Professor ZENG Xiaodong**, Executive Director of UNESCO INRULED. The study revealed the differences between rural and urban schools in terms of the use of digital methods and career support for teachers. Based on the findings, the paper proposed that a more precise investment model should be provided for rural schools to enable sustainable and quality improvement in rural education.

The development path of rural education and excellent cases of smart villages

Dr. Pietro Borsano, Executive Deputy Director (Industrial and Global Alliances) of School of Integrated Innovation (SCII) of Chulalongkorn

University in Thailand, shared his insights about the development of the digital economy across the 10 Southeast Asia economies and how the pandemic accelerated the digital transformation of SMEs, with a notable growth of digitalization in non-metropolitan areas of Southeast Asia.

Mr QI Zhiwen, Dean of the Department of Higher Vocational Education in Gansu Institute for Education Research (GIER), pointed out the analysis and suggestion of their team on the imbalanced development of rural schools, particularly, boarding schools and small-scale schools in rural areas.

Professor Morshed M Ahmad, Head of the Department of Development and Sustainability at Asian Institute of Technology (AIT) of Thailand, shared the comparison research conducted in three countries. He stressed that the government should issue long-term plans and framework to help recover from the pandemic.

Professor Kiichi Oyasu, Director of Educational Cooperation in Asia-Pacific Cultural Centre for UNESCO (ACCU), introduced the challenges that Japanese rural areas faced in development, particularly in an aging society. He shared the solutions and cases of disaster prevention and building smart communities.

Dr. Nguyen The Manh, Rice Programme Manager of Rikolto in Vietnam and Rice Programme Director of Rikolto in Southeast Asia, introduced various ways that minority ethnics in Vietnam used to cope with climate changes.

Mr Emmanuel Krou N'Guessan, President of the NGO GA-TIC, Côte d'Ivoire, and the winner of the 2021 UNESCO-Confucius Literacy Prize, shared his experience in decreasing illiteracy among women in his country and proposed his vision of prompting digital transformation in Africa with the help of ICT and International cooperation.

Dr. Shoukat Ali, Associate Professor from the University of Agriculture Faisalabad in Pakistan, talked about various digital initiatives launched by the School Education Department of Punjab Pakistan. The study of his team contributed to improving and sustaining quality education through the recommendations.

Mr Asrul Sidiq, a lecturer at Syiah Kuala University and researcher at the International Centre for Aceh and Indian Ocean Studies (ICAIOS), discussed processes and outcomes of TORA — the reform of land making use of land titling to improve management and protection of natural resources.

Mr Bounkham Phonedalom, Director of Permanent Secretary Office, Ministry of Foreign Affairs of the Lao PDR, gave a presentation about how the agricultural information through the use of ICT has impacted on vegetable growers/farmers in Vientiane province, Lao PDR.

Smart Village and Rural Education Transformation
Key takeaways

- In the process of digital transformation in education, it is necessary to prevent new regional differences and urban-rural differences, bridge the digital divide and the gap in the application of smart technologies, and build an inclusive and equitable culture.

- The university's research team is stationed in the countryside and coordinates with the teachers and students of the experimental school to carry out research work around related research problems, and explores ways to improve quality and efficiency by discovering problems and solving problems.

- To achieve digital transformation in rural schools, we shall always focus on lifelong learning, provide the software and hardware facilities and open education resources the school needs, connect schools, modify teaching methods, and reduce the gap between urban and rural areas.

- "Skills passport" creates a digital smart space that allows learners to recognize and record their skills. This is especially beneficial to rural communities, which could pave the way for them to find better employment opportunities within the country and abroad.

- The rural boarding schools and rural small-sized schools have been the weak parts of the high-quality and balanced education system, and are generally faced with the issue of “migrating out”. Although the conditions like infrastructures and facilities in these two types of schools have been improved in recent years, the key elements to promote the high-quality development of education, such as teacher team construction, school governance, and teaching quality, still have crucial needs.

- Smart and sustainable rural development needs to find "attractions" through infrastructure development, capacity development of stakeholders, inter-generational learning, collaborations, and conversions for innovation.

AI-driven Open Education

Nowadays, artificial intelligence (AI) is widely used in educational technology products and plays an increasingly prominent role in the entire field of education. The application of AI provides great opportunities and possibilities for open education, and also provides educational institutions with a variety of ways to organize teaching activities. The forum touched on topical issues on the deep integration of AI and education, the reform of evaluation empowered by AI, ethics of AI, the openness of education, etc.

AI in open education

Dr. Mohamed Jemni, Director of the ICT Department of the Arab League Educational, Cultural and Scientific Organization (ALECSO), pointed out that artificial intelligence provides new possibilities for addressing challenges such as equity, inclusiveness and intelligence in education. It is also fundamental for achieving SDG 4. He believed open education is of great significance to promoting education equity and narrowing the digital divide.

Professor LI Song, Vice President of the Open University of China, noted that the Open University of China would build a platform for lifelong education, online education, flexible education, and foreign cooperation. At present, the transformation and upgrading of Radio and TV University, as well as the high-quality development of the Open University, have entered a new stage. Artificial intelligence will help improve the quality of education and learners' learning experience and will play a positive role in promoting the development of open education.

Professor Lilia Chniti from the University of Sousse in Tunisia delivered a speech on “Towards

MODERATORS

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Dr. ZHANG Xiangling
Beijing Institute of Education, China

SPEAKERS

Dr. Mohamed Jemni
Director, ICT department, ALECSO

Prof. LI Song
Vice President, Open University of China

Dr. Lilia Chniti
University of Sousse, Tunisia

Dr. LU Yu
Associate Professor, Beijing Normal University, China

Dr. Eamon Costello
Associate Professor, Dublin City University, Ireland

Dr. Rob Farrow
Researcher, Institute of Educational Technology at The Open University, Ireland

Dr. Soheil Salha
An-Najah National University

Dr. Abderrahim Ghassoub
Education Orientation and Planning Center - Rabat-Morocco

Dr. Qing Tan
Associate Professor, Athabasca University, Canada

Dr. Marek Wosinski
Arizona State University, USA

Open Intelligent and Innovative Learning". She pointed out that technology can facilitate learners' learning and can be applied to educational evaluation. She proposed a "blended learning framework" that includes elements such as teaching and learning practice, resources (content), assessment, teacher capacity development, and inclusive facilities. She also elaborated on integrating artificial intelligence and education from three dimensions: resources, learner, and teacher.

Ethics of AI

Dr. LU Yu, Associate Professor from Beijing Normal University, discussed how artificial intelligence could promote education. He believed people need to understand the process and basis of the decision-making model of artificial intelligence. "Explainability" has become a key factor in deciding whether artificial intelligence can be widely applied. The role of explainable artificial intelligence in promoting education is a research question worthy of attention.

With the development of technology, the importance of the openness of education and the ethics of technology has become increasingly prominent. **Dr. Eamon Costello** from Dublin City University and **Dr. Rob Farrow** from The Open University of Ireland discussed issues on open educational resources (OER), open educational practice, and artificial intelligence ethics. They also proposed a framework for artificial intelligence ethics.

AI-driven assessment

Dr. Abderrahim Ghassoub from an Education Orientation and Planning Center (called Rabat) in Morocco talked about the difference between artificial intelligence and human intelligence. He emphasized the need to increase investment in research and development to improve the AI-driven evaluation system and to strengthen teacher training for better application of artificial intelligence teaching tools.

Dr. Qing Tan from Athabasca University gave a presentation on "Content Validation using Machine Learning - Open Learning Content Creation Platform". He proposed a platform driven by machine learning technics for creating open learning content, using artificial intelligence algorithms to enhance the ability of content verification and learning behavior analysis, using blockchain technology to improve the credibility and traceability of creation, aiming to better support individualized learning among users.

Mr FAN Xing, Co-Founder and CTO of Squirrel AI, focused on how the application of artificial intelligence software and hardware in education can improve students' autonomous learning ability and truly help lessen the burden of both students and teachers for greater efficiency.

Dr. Marek Wosinski from Arizona State University pointed out that education can promote the knowledge, skills, values and actions required for sustainable world development, and technology plays an important role in it.

AI-driven Open Education
Key takeaways

- Deploying AI for education effectiveness requires the digital transformation of educational systems, preparation for the effective and human rights based use of AI, and capacity building of educators and learners on AI technologies and applications.
- Due to the complexity the internal structure and intransparent decision processes, deep learning models are hard to provide clear and easily understandable explanations and interpretations. Fortunately, explainable artificial intelligence (xAI) can be an effective tool to tackle the interpretability issue of deep learning models.
- Open Learning Content Creation is an innovative solution to continue updating course content and to provide personalized learning.
- One-on-one personalized teaching through artificial intelligence teachers and a real facilitator/teacher could effectively achieve large-scale individualized learning and improve the teaching quality.
- Investing in the professional qualification of teachers for effective uses of assessment could be based on artificial intelligence tools and applications.

Digital Governance of Education

As a strategic technology leading the future, artificial intelligence has been elevated to a national strategy in major countries and regions in the world, and the application of artificial intelligence has provided new teaching methods for education as well as solutions to teaching problems, which has led to the reform of teaching models and a huge leap forward in education. The government grasps the social situation and public opinion in a timely manner, uses quantitative methods to improve work efficiency, and solves the problem of uneven distribution of resources in various industries, making "smart+" a new development trend in the field of education and people's livelihood. This forum discussed how intelligent technology would be deeply integrated with education, people's livelihood and other fields to provide new horizons, new ideas and new paths for the digital governance of education.

Professor WANG Yaonan, Academician of Chinese Academy of Engineering, introduced the cutting-edge trends of digital and intelligent technology. He introduced a digital technology system constituting memory technology, perception technology, action planning and machine learning. This system is not only the cornerstone of a highly autonomous and networked closed-loop control system and multiple application scenarios but also provides possibilities for improving the government's educational supervision function, innovating teaching reform models and offering new learning styles for students. In the future, with the intelligent technology, the collection of educational data will be more complete, the analysis will be more precise, and the understanding will be more accurate. The digital technology system will provide a scientific basis for educational decision-making and form a new path for the digital governance of education.

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Academician of Chinese Academy of Engineering

Ms SONG Shanping
Executive Dean, China Institute of Education and Social Development (CIESD)

Prof. TANG Yayang
Secretary, Party Committee of Hunan University of Science and Technology, China

Dr. Eugene G. Kowch
Former President, Association for Educational Communications and Technology (AECT)

Dr. Ig Ibert Bittencourt
Associate Professor, Co-Director, Center of Excellence in Social Technologies, Federal University of Alagoas, Brazil

Dr. TONG Lili
Associate Professor, Beijing Normal University, China

Dr. Mutlu Cukurova
Associate Professor, University College London, UK

Penal Discussion

Mr JIANG Yanshuang
Office Director, Educational Informatization Strategy Research Base (Beijing), Ministry of Education, P.R.C

Mr WEI Xiaoliang
Deputy Director, Shenzhen Education Information Technology Center, China

Mr XUE Gang
Director, E-Education Center of Erdos, Inner Mongolia, China

Ms XIAO Chenhui
Principal, Chnagtangli Primary School, Yuhua District, Changsha, China

Mr WANG Xianguang
Vice Principal, Guangxi Rongshui Miao Autonomous County Ethnic Senior Secondary School, China

Mr ZHENG Furui
General Manager, Higher Education Division of Beijing Business Center, Hikvision

Ms XU Bingyu
Inspector General, Education Division, No.2 Division Company of Beijing Unicom

New directions for policy-making and governance

Ms SONG Shanping, Executive Dean of the China Institute of Education and Social Development (CIESD), stressed that the tasks of the digital governance of education are realizing the transformation from “digitalization + education” to “education + digitalization” and developing digital education with humanistic characteristics. As the first high-end think tank dedicated to the research of education and social governance in China, CIESD will conduct research on governance strategies of education reform and development, release high-quality outcomes, and provide strong support for promoting the educational governance system, accelerating the modernization of education and building a powerful nation of education.

Professor TANG Yayang, Secretary of the Party Committee of Hunan University of Science and Technology, noted that rural areas are at a relative disadvantage in the construction and governance of the digital education environment. To achieve rural revitalization, improve education equity and promote the realization of the national strategic goal of high-quality development of education, we must pay attention to three governance directions:

- rural education is the focus of modernization of educational governance;
- digital environment is the difficulty of the governance of rural education; and
- students are the central focus of construction of digital environment of rural education.

Based on the three directions, he suggested we should make plans, focus on key points, promote implementation, and effectively carry out digital governance to promote the high-quality development of rural education, especially on the problems and obstacles in rural areas.

Dr. Eugene G. Kowch shared his thoughts on the innovation policy-making framework for AI-enhanced education. He stressed that policy formulation should change the focus from linear to non–linear system to include inequity, poverty, and environmental problems. The economy, society, culture and other factors should be

considered to form a policy network. He argued that the key to integrating education and AI is cultivating effective managers and educational governance mechanisms.

Dr. Ig Ibert Bittencourt noted that smart education should focus on improving the quality of teachers and students based on the local needs. The Federal University of Alagoas in Brazil has developed a series of applications and systems in response to problems such as education imbalance and insufficient writing skills of students, which aims to improve the teaching quality, better realize the implementation of educational policies and applications, effectively promote the research and development based on the real demand, and improve the level of digital governance of education.

Ms TONG Lili, Associate Professor from Beijing Normal University, delivered a speech on "The Application and Governance Strategy of Full-cycle Internet Education from the Perspective of Technological Experiments". In response to the new requirements of digital governance of education and the latest developing trend of Internet + education, she shared five key technical experiments of closed-loop governance, including a review of multimodality teaching content, protection of personal information, user behavior portrait and algorithm analysis, and risk monitoring for Internet education applications.

These technical experiments are aimed to actively explore the governance strategies of full cycle Internet + education, open up the design concepts and practical applications of the technology used for Internet + education, and establish a full-cycle governance model for the application of Internet + education.

Dr. Mutlu Cukurova, Associate Professor from the University College London, found that the use of intelligent technology in the teaching process can increase interactivity and improve teaching efficiency. The integration of intelligent technology into classroom activities will encourage the innovative design of teaching scenarios, provide a practical basis for analyzing human behavior, and build a visual module of human emotions and IQ, thereby effectively improving the fairness and efficiency of the classroom.

Pathway and solution for digital governance of education

The penal discussion focused on the "pathway and solution for digital governance of education" and discussed its mechanism construction, current plan, optimization and exploration from multiple perspectives, including governance of regional education, teaching scenarios in the school context, and the application of digital technology.

Digital Governance of Education
Key takeaways

- For policy-making in smart artificial intelligence education contexts, it is suggested to shift from narrow (subsystem) innovation understanding in complex education systems to broad (ecosystem) innovation understanding, and shift from economic and mission-oriented technical policy at local, and national levels to society problem-focused policy-making networks.

- For today's Internet+education applications, young students learn online (e.g. online virtual learning environments) for most of the time. Assessing their learning effects in objective way requires educators to carry out technical simulation of the online perception environment to evaluate the learning effect. These experiments needs multi-party collaboration, including technical experts designing simulated scenes and researchers conducting data analysis.

- Digital governance is the periodical result of digital transformation. Three key points in the transformation process are following the user first principle, providing timely feedback through multi-party collaboration, and regional coordination that ensures the basics and accessibility.

- Concerning the establishment of platforms at district and municipal level, Shenzhen realized the school collaborative work mechanism through financial support, set up informationized team through establishing information center in each school, encourage cooperation between universities.

- For countryside schools in ethnic minority, the transformation to smart schools can bring convenience to students' lives and relieve teachers' work pressures. The cooperation between veteran teachers and pre-service teachers can promote the application of informatized resources and teaching effectiveness.

Reform of School Education in the Intelligent Era

The development of the new generation of information technology has promoted the transformation of school education. The intelligent era has put forward a new test for the integration of technology and education from the aspects of concept, path, system and model. New changes are required in school education to adapt to future digital developments. It is of vital importance to pay attention to the opportunities and challenges brought by school education reform to teachers and students.

Education reform driven by intelligent technology

Professor HU Qintai, Secretary of the Party Committee of Guangdong University of Technology, believed the advent of the intelligent era has brought major changes in the educational environment and has also put forward new goals and requirements for school education. We shall actively promote the in-depth integration of intelligent technology and education, apply student-centered learning, and promote innovation in educational concepts, pedagogic approaches, and management models. We shall strive to cultivate creative talents and lay a solid foundation for achieving educational equity, building a high-quality educational system and a more open and inclusive lifelong learning system.

Professor LIU Jian, Dean of China Education Innovation Institute of Beijing Normal University, pointed out that intelligent technology not only brings a new educational mission but also provides strong support for promoting fair and quality education. The starting point for studying the futures of education is to reflect on and

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Prof. KE Qingchao
Vice Dean, School of Information Technology in Education, South China Normal University

Prof. LI Yushun
Faculty of Education, Beijing Normal University, China

Prof. LUO Fang
Faculty of Psychology, Beijing Normal University, China

Prof. CAO Xiaoming
Faculty of Education, Shenzhen University, China

Prof. Anthony Seldon
President and co-founder, International Alliance for Active Education, UK

Dr. Christina Hong
President, Technological and Higher Education Institute of Hong Kong (THEi), Hong Kong, China

Ms GAN Lu
Pre-school Teaching Researcher, Longhua District Education Science Research Institute, Shenzhen, China

Mr SONG Yan
Director, Information Center, Beijing Eleventh School, China

Ms ZHANG Jia
Secondary School Researcher, Teacher Development Center, Suzhou Industrial Park, China

Ms CHENG Xin
Director, Educational Technology Office of Tianjin Yinghua International School, China

discuss how school education will be reformed in an intelligent era. He believed aspects of school education in this intelligent era are likely to be changed in this fashion: top-level design, student learning styles, data-driven teaching, and the construction of a collaborative education ecosystem connecting schools, families, and society.

Professor LI Yushun from Beijing Normal University highlighted the developing trend of smart campuses. He noted that intelligent technology drives the construction of a smart campus. With the enhancing technical features and the increasing application of information technology in the teaching process, teaching has gone through a big change. The data-empowered smart campus and precision teaching together promote the development of quality education.

Professor KE Qingchao from South China Normal University focused on the cognitive revolution and school teaching innovation in the intelligent era. He stressed that the development and superposition of AI (Artificial Intelligence) technology would subvert human's cognitive boundaries and bring a new cognitive revolution to human beings. The school teaching reform and innovation in an intelligent era need "brain-based learning", which is based on the research of brain science and AI. In the process of promoting the deep integration of AI and education, it is expedient to conduct various educational social experiments, and to study and judge the development trends, risks and challenges of intelligent education.

Professor LUO Fang from Beijing Normal University shared her findings from an"Intelligent Assessment of Mental Health". She discovered that psychological measurement in an intelligent era is becoming more precise, and the measurement method will be transformed from the traditional self-report scale to intelligent assessment. Text information in the social media, wearable sensor data, and audio and video data can be analyzed by AI, achieving a seamless and accompanying assessment of students' mental health.

Professor CAO Xiaoming from Shenzhen University delivered a speech on "Reform and Remodeling - The Prospects of School Education in the Intelligent Era". He put forward eight characteristics of the futures of schools: focusing on fostering global citizenship skills, innovative and creative skills, technical skills, and interpersonal skills; putting emphasis on

individualized and autonomous learning, accessible and inclusive learning, problem-based and cooperative learning, and lifelong and self-driven learning.

Professor Anthony Seldon, who is the President and Co-Founder of the International Alliance for Active Education and the author of "The 4th Education Revolution", explained how to change the traditional educational concepts and methods to make students better adapt to the changing society. He gave a detailed presentation on how intelligent technology has changed education, including the management and supervision of the educational system as well as education in rural areas. Also, the development of technologies such as the Internet and VR provides more choices for reading textbooks and conducting assessments.

Dr. Christina Hong, President of Technological and Higher Education Institute of Hong Kong (THEi), shared her vision of the futures of smart learning. She introduced the construction of a smart campus at THEi, the education and training of Hong Kong Vocational Education to cultivate STEM (science, technology, engineering, and mathematics) talents for the development of smart cities, and some examples for the next-generation campus. She suggested the top 10 digital skills Education 4.0 demands: complex problem solving, critical thinking, creativity, people management, coordinating with others, emotional intelligence, judgement and decision-making, service orientation, negotiation, and cognitive flexibility.

School cases of technology-supported education

Ms GAN Lu, Chief Principal of Preschool Education Group of Longhua District Education Science Research Institute in Shenzhen, focused on how information technology empowers children's inquiry-based learning. She introduced three important roles that information technology plays in children's learning progress: children being "indigenous people" in the information age, inquiry-based learning for children, and environmental support. She further enumerated three typical cases of how technology is integrated into teaching.

Mr SONG Yan, Director of the Information Center of Beijing Eleventh School, gave a presentation on technology-empowered school transformation. He introduced how Beijing Eleventh School uses intelligent technologies for a new school form, including the topics on the top-level design of school informatization, technology-assisted classroom projects, project-based learning and online learning, and Internet service purchase.

Ms ZHANG Jia, a secondary school researcher at the Teacher Development Center of Suzhou Industrial Park, emphasized technology-empowered project-based learning, aiming to provide every child a "good" learning experience. She shared the experience of developing smart education in Suzhou Industrial Park from the aspects of growth, exploration, and the future.

Ms CHENG Xin, Director at the Educational Technology office of Tianjin Yinghua International School, focused on the "Paths and Practices of Digital Transformation in Primary and Secondary Schools". She shared the exploration of smart education practice in Tianjin Yinghua International School, including the blueprint framework of Smart Yinghua, solutions on data island, the construction of business systems based on data center, the path of smart Yinghua's construction and thinking of digital transformation.

Reform of School Education in the Intelligent Era
Key takeaways

- The reform of school in the intelligence era includes but not limited to building high-quality education system from multiple perspectives such as policy, theory and practice; focusing on students' development and promoting personalized learning; using big data to achieve data-driven teaching and learning; and constructing innovative educational ecology in which government, schools, enterprises, families, and society make joint contributions.

- With the accelerated development of intelligent technology, classroom teaching is moving towards openness, and the integration of online and offline modes brings about the reconstruction of time and space, enhances students' learning ability, and promotes the transformation of the modernity of the classroom.

- To a certain extent, the solidification of the learning space directly restricts the flexibility of teaching and curriculum, and indirectly affects the development and cultivation of learners' personalized ability. It is a bottleneck problem that needs to be broken through in the implementation of educational reform in modern schools.

- The digital transformation of the school is the result of the digital transformation of each specific departments in a school, where all the personnel is trained to develop their information literacy and technology application capabilities.

- Rather than a bricks and mortar approach, the next generation campus approach shall be an ecosystem approach where we have the relationships between the education provider, the industry in the profession, the community and the student as our learning partner.

Leveraging Intelligent Technology for Education Innovation

Leveraging the technology for assessment and talent cultivation

Professor CHEN Li from Beijing Normal University highlighted "Intelligent Technology-based Performance Assessment and Monitoring of Students' Comprehensive Development". She believed evaluation is the baton of educational reform and development, and she found that evaluation in real educational contexts still needs improvement. For example, the traditional paper-and-pencil tests are not able to test students' multi-faceted abilities. She suggested 3 future directions: improving the existing limitations of comprehensive quality evaluation, constructing a basic database for the comprehensive development of Chinese students, and revealing the law of the development of comprehensive literacy of Chinese students.

Dr. XIN Bing, Director of the Children & Youth Science Center (CYSC) of the China Association for Science and Technology, proposed 3 initiatives on "The Thinking and Practice of Educating People Through the Combination of Technology and Education". The first is to seize the opportunity of the history of the information revolution and use information technology to empower the development of educational innovation. The second is to build a platform for international exchanges and jointly cultivate global youth science and technology talents. The third is to vigorously strengthen online and offline cooperation to jointly cope with the challenges of science and technology education.

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Prof. HUANG Xiankai
Secretary, Party Committee of Beijing Technology and Business University, China

Dr. Sanjaya Mishra
Director in Education, Commonwealth of Learning (COL), Canada

Mr WU Fei
Head, Expert Group of Artificial Intelligence and Science and Technology Innovation, Ministry of Education, P.R.C

Prof. Hirotaka Nanba
Hiroshima University, Japan

Prof. WU Wenjun
Beihang University, China

Dr. Joseph South
Chief Learning Officer, International Society for Technology in Education (ISTE), USA

Prof. Alan Lesgold
Dean (2000-2016) & Professor Emeritus, University of Pittsburgh, USA

Prof. Ebba Ossiannilsson
Chair, ICDE OER Advocacy Committee, Sweden

Professor HUANG Xiankai, Secretary of the Party Committee of Beijing Technology and Business University, believed digital education had become an important part of the national development strategy, and digital transformation is the key to the transformation of higher education. Beijing Technology and Business University have built a Digital Future Center which interconnects all kinds of digital resources. Realizing the transformation of digital talent training in business could be achieved through building an integrated platform for intelligent teaching to realize the digitization of management processes and constructing a teaching space for digital interaction between teachers and students.

Technology-empowered innovative teaching and learning

Professor ZHU Wenwu, Deputy Head of the Department of Computer Science and Technology (DCST) of Tsinghua University, focused on autonomous-driven machine learning. He noted that the overall idea of autonomous-driven machine learning is similar to that of pedagogy, which needs to be adjusted from both internal and external states. That is to say, adjusting learning goals and choosing learning strategies based on the learning environment and students' own state. Pedagogical ideas play a guiding role in the development of machine learning, and vice versa, the development of artificial intelligence technology will further promote the technological transformation of education.

Mr WU Fei, Head of the Expert Group of Artificial Intelligence and Science and Technology Innovation of the Ministry of Education, P.R.C, noted that we had entered a data-intensive era, where we can collect thousands of data that characterizes different human behaviors and patterns. The connotation of artificial intelligence is data-supported models and algorithms, computing power and systems, scenarios and applications. On the basis of this connotation, technology can be formed to intersect in different fields or different scenarios.; therefore, artificial intelligence technology must be combined with scene applications to promote the advent of the intelligent era.

Professor WU Wenjun from Beihang University delivered a speech on "Research and Thinking of Group Intelligence in Smart Education". He stressed that we could learn from the model of Open Source Community to build a group learning space so that the group intelligence would be better formed. In his view, we could first design a group organizing structure and interaction model for teaching; then, we construct a hybrid, effective learning incentive mechanism and provide a series of intelligent auxiliary tools such as cognitive modeling, homework review, human-computer mutual evaluation, performance prediction, etc., with an aim to build a more complete group pattern and intelligent learning space.

Professor Emeritus Alan Lesgold from the University of Pittsburgh gave a presentation on "Enculturating Smart Learning Technology". He believed that technology could facilitate interaction between people, which is when learning happens. The key lesson learned from past practices of learning improvement is that we need to narrow the cultural knowledge gap required to acquire and apply new technologies as much as possible. The knowledge and culture of technology application play an important role in the successful deployment of new technologies.

Professor Hirotaka Nanba from Hiroshima University shared his research results from a comparative study of paper reading and digital reading in medium-scale and small-scale schools. He suggested that

- digital reading should not be introduced in the lower grades but in the middle grades and firmly implemented in the upper grades;
- digital reading is suitable for objective reading comprehension while paper reading is suitable for immersive reading.

Professor Ebba Ossiannilsson, Chair of the ICDE OER Advocacy Committee, focused on Mainstreaming OER. She pointed out that open education is the only way to achieve the equality and lifelong learning advocated by UNESCO. Open access to educational resources is essential for the sustainable development of education and the achievement of human rights equality. OER is public resources, including various teaching resources, media and platforms, which are publicly authorized and accessible to all and can be re-edited, copied or distributed to third parties for use.

National Smart Education Strategy for teaching and learning

Dr. Sanjaya Mishra, Director of Education of Commonwealth of Learning (COL), gave a presentation on "Smart Education Strategies for Teaching and Learning". He shared a report on the strategy of smart education in teaching and learning, related case studies and a framework for smart education. He believed smart education could be defined from three aspects: the first is to enable people to immerse themselves in learning and transfer knowledge; the second is the innovative application of technology, interactive participation and the availability of learning resources; and the third is the ethical aspect, which needs to focus on cybersecurity and equity issues.

Dr. Joseph South, Chief Learning Officer of the International Society for Technology in Education (ISTE), believed that the core idea of the "Rethinking and Redesigning National Smart Education Strategy" is to transform teaching and learning through technology. He explained it from 3 aspects:

- transformative teaching and learning enabled through technology;
- a digital learning environment conducive to smart education; and
- forward-thinking governance and policy initiatives.

Under the impact of the COVID-19 pandemic,it is difficult for us to return to the original form of teaching, so we need to examine existing teaching methods, create new teaching methods, think about the right teacher-student relationship, and build a strong learning community to create a good learning environment.

Leveraging Intelligent Technology for Education Innovation
Key takeaways

- We must break through a series of key intelligent technologies, say, those for collection, analysis and traceability, to achieve process-based performance evaluation. For example, collecting data from multiple sources such as schools, families, communities, science and technology venues, etc. could help to achieve data integration and cross-platform data aggregation, realizing the objective recording of learners' performance.

- It is very important to accelerate the construction of a high-quality personnel training system for the vast number of young people to advocate the scientific spirit, establish scientific thinking, master scientific methods, and enhance their practical ability.

- Technology will not be used well and extensively for teaching and learning unless it enacts an approach to learning that comes close to what was done by good teachers before that technology existed and unless the skills needed to employ the technology are already adequately enculturated into our society.

- We need to examine the whole process of managing a school from digital perspective - to examine the digital transformation of universities from macro perspective, examine digital management from mid-level perspective, and examine smart classrooms from micro perspective.

- The implementation of smart education policy has five levels: global smart education and AI in education frameworks; geopolitical/Regional level; national transversal level; dedicated smart education policies/strategies; and ministerial level taskforce.

- It is recommended to develop strategies to monitor the educational effectiveness and long-term financial efficiency of OER, which include participation of all relevant stakeholders. Such strategies could focus on improving learning processes and strengthening the connections between findings, decision-making, transparency, and accountability to inclusive and equitable quality education and research.

Concluding Comments and Follow-up Actions

Professor ZHOU Zuoyu, Vice President of Beijing Normal University, made a concluding speech for GSE2022. He pointed out four spotlights of this year's conference:

- the learning crisis and the futures of education were discussed from the perspective of students;
- the exploration of how intelligent technology supports the digital transformation in education featured by all elements, all businesses, all processes and all fields from the perspective of two-way empowerment of technology and education;
- the launch of Initiative for Global Smart Education Network (GSENet) for building an international exchange and cooperation network;
- the released outcomes on the GSE 2022 includes home and abroad research results: "Rethinking and Redesigning National Smart Education Strategy" and "Report on the Construction Progress of Smart Education Pilot Zone & Best Practices on Smart Education".

Ms XIA Juan, who is the Deputy Director of the China Center for International People-to-People Exchange, Ministry of Education, P.R.C (CCIPE), thought the agenda of GSE2022 was rich in content and insightful and provided diverse ideas, experiences and cases for education practitioners in China and other countries in the world, which is of great practical significance. The technology-empowered education could be further promoted through people-to-people

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Prof. LIU Dejian
Co-Dean, Smart Learning Institute of Beijing Normal University, China

Prof. ZHAN Tao
Director, UNESCO IITE

Prof. HUANG Ronghuai
Co-Dean, Smart Learning Institute of Beijing Normal University, China

International Report of Supportive Environment on Artificial Intelligence Courses in K-12

Prof. LI Yanyan
Co-Director, Lab of Knowledge Modeling and Analysis of National Engineering Research Center of Cyberlearning and Intelligent Technology, China

exchanges. She hoped all relevant parties could build more platforms to create more opportunities for schools, teachers and students to communicate in smart education, promote mutual learning between Chinese and foreign schools, and promote the popularization, application and improvement of technology in teaching and learning.

Releasing the *International Report of Supportive Environment on Artificial Intelligence Courses in K-12*

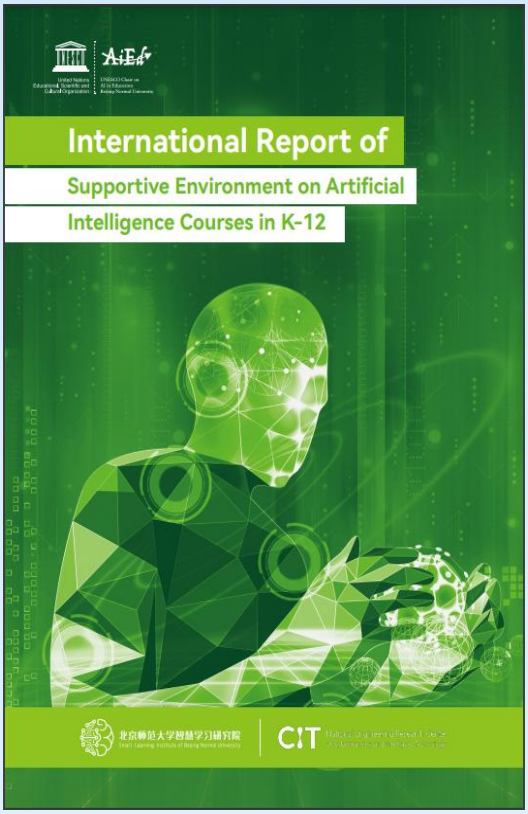
Professor LI Yanyan, who is the Co-Director of the Lab of Knowledge Modeling and Analysis of the National Engineering Research Center of Cyberlearning and Intelligent Technology, released the “International Report of Supportive Environment on Artificial Intelligence Courses in K-12”. In this report, the development of artificial intelligence education in primary and secondary schools around the world is summarized, and recommendations are made. She presented six key points on how AI will be developed in the future:

- the development of AI is based on open educational resources;
- the design of teaching materials needs to take into account the student's needs;
- it is necessary to improve the basic knowledge on an algorithm for teachers;
- the AI teaching laboratory plays an important role in the basic process of developing AI for teachers;
- education policies should support sustainable development; and
- we should pay attention to the safety and ethics of AI.

International Report of Supportive Environment on Artificial Intelligence Courses in K-12

With the development of big data, computing power, and machine learning algorithms, the application of AI technology is becoming more and more common in various industries and people's daily life. The integration of AI and education is becoming closer and closer. How to use AI technology to improve education quality and teaching efficiency, and how to cultivate professionals who master AI technology have become the focus of global attention. In 2019, the president of the People's Republic of China Xi Jinping to International Artificial Intelligence and Education Conference pointed out that grasp the global AI development situation, find the breakthrough and main direction, cultivate a large number of innovation ability and cooperation spirit of AI high-end talents, is the important mission of education. As an important result of the meeting, more than 100 member countries and UN institutions, AI, civil society and the private sector of about 500 representatives jointly published the BEIJING CONSENSUS — AI and education (Beijing consensus), The consensus is committed to implementing appropriate policy strategies through AI and education system, comprehensive innovation education, teaching, and learning methods. In addition, the consensus is to use AI to speed up the construction of an open and flexible education system to ensure that people enjoy fair, suitable for everyone, and high-quality lifelong learning opportunities. This will thus promote the realization of the Sustainable Development Goals and a community with a shared future for mankind. At the opening ceremony of the AI and Education International Forum, Chinese Education Minister Huai Jinpeng stressed the importance of AI in education, and mentioned that "AI will give education power, change education and innovate education, which will undoubtedly create a better future for everyone else."

To promote youth AI education and analysis of the supportive environment, the National Engineering Research Center for Cyberlearning and Intelligent Technology joined the Smart Learning Insitute of Beijing Normal University in carrying out the International Report of Supportive Environment on Artificial Intelligence Courses in K-12. This report aims to, through all kinds of data collection, summary, analysis, and comparison, for academia, education, and industry to provide a comprehensive understanding of the supportive environment for AI courses in K-12. The report also discusses the key elements that affect K-12 learning in AI courses. For instance, it includes teaching techniques for K-12 students, such as assigning independent learning, analyzing possible trends for the future AI development of youth education, and providing sufficient teaching resources for teachers, scholars, or other personnel.



Professor LIU Dejian, Co-Dean of Smart Learning Institute of Beijing Normal University, noted that idealized education is future-oriented and learner-centered. Idealized education could be further developed by considering the application of intelligent education products and tools, promoting human-computer cooperation, and supporting flexible learning for students. With the help of smart educational technology tools, students receive guidance and coaching, resources, and targeted learning when needed. On-demand learning is an important learning mode in the future, making students' learning easier and their lives better.

Professor ZHAN Tao, Director of UNESCO IITE, pointed out that the word "SMART" brings us together. For the sake of a common mission and goal, we need to constantly learn about the new digital transformation of the education system. Only through cooperative activities, meeting new partners, achieving goals together, and building a new educational system can we build smart education in such a challenging historical period.

Professor HUANG Ronghuai, Co-Dean of Smart Learning Institute of Beijing Normal University, made the concluding report. He concluded five spotlights of this year's conference:

- the conference embraced openness and cooperation, featured by 28 international partners and 12 thematic forums;
- the conference produced global impact with more than 200 domestic and overseas speakers;
- welcoming multicultural guests by providing 5 participant modes, namely, live streaming, main venue, local venues, ZOOM meeting, and metaverse exhibition;
- the Initiative for Global Smart Education Network (GSENet) was launched; and
- the "Report on the Construction Progress of Demonstration Zone of Smart Education" and the best practices on Smart Education were released.

He also talked about five concerns:

- the fields of technology and education are both actively influencing each other and showing a development trend of systematic integration;
- in the face of uncertain crises, the Futures of Education needs a new social contract for transformation, and young students shall take concrete actions to promote the global development initiative;
- we shall not only make full use of intelligent technology to empower teacher professional development but also examine the challenges of teacher education and teacher development brought by the intelligent era in an objective and rational manner;
- building the new ecology of smart education includes but is not limited to the planning of digital strategy and system, the construction of new infrastructure, technology-supported pedagogic transformation, and technology-empowered innovative evaluation; and
- rural revitalization is facing a major issue in all countries. We shall pay equal importance to construct the smart village and the smart city to transform rural education effectively.

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Appendix: Concept note

Global Smart Education Conference 2022

Launching of Global Smart Education Network (GSENet)

Intelligent Technology and Digital Transformation in Education

18 - 20 August 2022



Synthesis Report

Background

Intelligent technologies, such as Artificial Intelligence, Big Data, and VR/AR/MR, are important driving forces leading a new round of scientific and technological revolution. These technologies are profoundly changing the way we live, work, think, and even accelerating social transformation and deepening educational reform.

Affected by the ongoing pandemic wave, global education is becoming more uncertain and fragile than ever. Numerous efforts have emerged to respond to the challenges of COVID-19 at the international level. As the 2030 deadlines are fast approaching, the United Nations intend to convene a Transforming Education Summit in the coming September to mobilize action, ambition, solidarity and solutions with a view to transforming education before 2030. In tandem, many countries and organizations rolled out digital development strategies at the national level to promote a comprehensive digital transformation in education. UNESCO released the *Beijing Consensus* at the first edition of the International Conference on

Artificial Intelligence and Education. The *Beijing Consensus* recommends making appropriate policies that aim at systematic integration of AI and education to innovate education, teaching and learning. According to the report of *Digital Strategies in Education across OECD Countries*, a total of 17 member countries released digital education-related strategies between 2015 and 2019. Furthermore, the *Digital Education Action Plan (2021-2027)* issued by the European Union emphasizes two priority areas, namely, "Fostering the development of a high-performing digital education ecosystem" and "Enhancing digital skills and competences for the digital transformation".

The Chinese government also proposed a series of strategies and policies aimed at further promoting the systematic integration of intelligent technology and education. These include *China's Education Modernization 2035 Plan*, *The New Generation Artificial Intelligence Development Plan*, *Education Informatization 2.0 Action Plan*. In addition, the Ministry of Education of the People's Republic of China also stressed the importance of implementing the strategic action of education digitalization as well as accelerating the process of digital transformation and intelligent upgrade for education.

Digital transformation in the domain of education is based on digitization and digitalization, and is committed to 1) consolidating digital foundation; 2) building smart learning environments; 3) promoting co-creation and co-sharing of quality digital educational resources; 4) exploring personalized models for cultivating students and training teachers; 5) improving the digital literacy and digital skills of teachers and students; and 6) enhancing digital awareness, thinking and capabilities at digital transformation stage. Smart education can be considered as the educational behaviours provided by schools, regions, or governments, with the characteristics of high learning experience, learning content adaptation, and teaching efficiency. In smart education, modern science and technologies are used to provide diversified supports and on-demand services for students, teachers and parents, etc., the data of participants and learning and teaching processes are recorded and used to promote the quality and equity of education. From this perspective, smart education shall have great potential to be a breakthrough that integrates intelligent technologies with education for the future.

Beijing Normal University (BNU) is a comprehensive and research-intensive university with its strength in teacher education, educational science, and basic disciplines of liberal arts and sciences. BNU has taken the lead in the theoretical innovation and practical exploration of smart education. It has put forward policy suggestions on developing smart education and promoting the reform of the education system. It also serves as the secretariat of the expert group of the Smart Education Pilot Zones. During the pandemic, the Smart Learning Institute (SLI) of Beijing Normal University and the National Engineering Research Center of Cyberlearning and Intelligent Technology (CIT) have been seeking educational solutions under special circumstances. Specifically, they worked with UNESCO, finalizing and publishing a series of handbooks and guidance which comprise *Ensuring Effective Distance Learning under COVID-19 School Closures: Guidance for Teachers* as well as *AI and Education: Guidance for Policy-makers*. A variety of learning strategies and practical experience adopted in China have been collected in these publications, which provide institutions with feasible recommendations for minimizing disruption and ensuring continuity of course delivery during the pandemic.

UNESCO Institute for Information Technologies in Education (UNESCO IITE), as the co-organizer of the conference, is the only UNESCO Category One Institute that holds a global mandate for ICT in education. In 2020, IITE in cooperation with The Commonwealth of Learning (COL), International Society for Technology in Education (ISTE), National Research University - Higher School of Economics (HSE) and Beijing Normal University launched the Joint Project of Rethinking and Redesigning National Smart Education Strategy to explore the solution of infusing technology into education. IITE also worked together with SLI of Beijing Normal University, releasing a *Handbook on Facilitating Flexible Learning During Educational Disruption: The Chinese Experience in Maintaining Undisrupted Learning in COVID-19 Outbreak*. This handbook has been translated into several languages and was widely disseminated around the world.

Since 2016, BNU, in conjunction with international organizations and universities worldwide, has held four consecutive US-China Smart Education Conferences (UCSEC) and two Global Smart Education (GSE) Conferences. Thousands of experts and scholars in the field of education and technology from more than 50 countries and international organizations, including UNESCO and OECD attended the meeting. These conferences held discussions on frontier fields and hot issues such as K-12 Education, Higher Education, Vocational Education, Transforming Education through Intelligent Technology, AI and Future Education, Smart Learning and Futures of Education. At the conferences, a series of projects and research results such as *the Horizon Project Regional Report*, *the White Paper on Smart Education Pilot Zones Construction*, the Joint Project of *Rethinking and Redesigning National Smart Education Strategy*, as well as the project of E-Library for Teachers were released. The Global Competition on Design for Future Education also had a launch session at the conferences.

Aims

To promote the digital transformation and intelligent upgrade in education and strengthen international communication, BNU will convene the Global Smart Education Conference 2022 in conjunction with international organizations, universities and research institutions on 18th-20th August 2022. The theme of this conference is Intelligent Technology and Digital Transformation in Education. Experts and scholars from the fields of education and technology will be invited to discuss new theories, emerging technologies, latest achievements and trends in smart education globally to share relevant cases, build platforms for communication and to establish alliances for cooperation. In partnership with international organizations, GSE2022 will release a report of the Joint Project of Rethinking and Redesigning National Smart Education Strategy, a case collection on smart education, a white paper on smart learning environment, and a portfolio of Global Competition on Design for Future Education, etc.

The Global Smart Education Conference 2022 is organized by Beijing Normal University, co-organized by UNESCO Institute for Information Technologies in Education, and jointly hosted by Smart Learning Institute of Beijing Normal University, China Institute of Education and Social Development, Collaborative Innovation Centre of Assessment for Basic Education Quality, National Engineering Research Center of Cyberlearning and Intelligent Technology, Educational Informatization Strategy Research Base of the Ministry of Education (Beijing), etc.

Sub-themes

- Intelligent Technology Empowerment for Smart Education
- e-Textbooks and Pedagogy under Digital Transformation
- Smart Environment and Evaluation for Digital Transformation
- Public Service System and Digital Governance of Education
- Rural Education and Smart Village
- Systematic Integration of Technology and Education

Provisional Agenda

Due to the COVID-19 pandemic, GSE2022 will be held in both onsite and online modes (Zoom Meetings). Some forums will be presented in the form of metaverse.

Date: 18th – 20th August 2022

Onsite venue: Changping campus of Beijing Normal University

Online venue: Zoom, Live streaming

Conference Agenda (Onsite and Online):

[China Standard Time (CST), UTC+8]

Date	Time	Agenda
18th August 2022 (Thursday)	14:30-18:00	Opening Ceremony & Forum on Digital Transformation for Smart Education
	19:00-23:00	Forum on Teacher Education in Metaverse World
	19:00-22:00	Forum on Promoting Digital Literacy in Smart Learning Environment
19th August 2022 (Friday)	9:00-18:00	Forum on the New Ecology of Regional Smart Education
	9:00-12:00	Teacher Forum on Technology Empowered Teaching Innovation
	14:30-18:00	Student Forum on Learning Crisis and Futures of Education
	14:30-20:30	The 6th International Conference on Smart Learning Environments
	19:00-23:00	Forum on Smart Village and Transformation of Rural Education
	19:00-22:0	Forum on AI-driven Open Education
20th August 2022 (Saturday)	9:00-12:00	Forum on Digital Governance of Education
		Forum on Reform of School Education in the Intelligent Era
	14:30-18:30	Forum on Leveraging Intelligent Technology for Education Innovation & Closing Ceremony

Target Participants

GSE2022 intends to invite academicians, experts and scholars, government officials, representatives of international organizations, school principals and teachers, and business leaders in the fields of education and technology to give keynote speeches (Speakers of the conference will be later announced on the website.).

GSE2022 also intends to invite policymakers, researchers, practitioners, technicians, industry practitioners, teachers and students in the field of smart education to participate in the conference offline or online.

Partners

We welcome global partners to join us to co-host the conferences, forums and parallel sessions.

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Institute for Information Technologies in Education

Global Smart Education Conference 2022

Launching of Global Smart Education Network (GSENet)

Intelligent Technology and Digital Transformation in Education

Synthesis Report

The Global Smart Education Conference 2022, held on August 18-20, explored the theme 'Intelligent Technology and Digital Transformation in Education'. This publication is a synthesis of the key discussions, focusing on the how intelligent technologies empower smart education, digital transformation in regional and rural education, the futures of education in the eyes of teachers and students, how digital governance of education can be enhanced to direct intelligent technologies to the common good for education and humanity.

Stay in touch

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