Shaping the Future of Learning:
The Role of AI in Education 4.0

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Contents

Executive summary

If deployed well, AI can help unlock solutions for improving global education systems.

As technological change accelerates, there is an urgent need for supporting education systems in managing new opportunities and risks. If managed well, technology – particularly artificial intelligence (AI) – offers a unique opportunity to help education systems enable Education 4.0 – teaching and learning approach that focuses on providing learners with the abilities, skills, attitudes and values fit for the future. Developed by a global coalition of education experts, practitioners, policy-makers and business leaders, Education 4.0 serves as a comprehensive framework that outlines key transformations needed in primary and secondary education to promote better education outcomes. AI can help broaden the reach of future-ready education systems and enhance their effectiveness in preparing students for the future. Yet, there are challenges and risks, for teachers and learners alike, that must be addressed and overcome to deliver on the promise of educational technology.

The adoption of emerging technologies in education, particularly AI, holds immense potential to revolutionize teaching methodologies, personalize learning experiences and streamline administrative processes. However, while AI can excel at tasks like presenting differentiated content and assuming many administrative duties, the complex process of facilitating learning requires more than mere dissemination of information. AI should therefore serve to enhance, not replace, the role of the teacher. By freeing educators from routine tasks, AI empowers them to focus on building relationships, understanding individual student needs and fostering motivation. This synergy not only improves teaching effectiveness but also underscores the indispensable human element in education.

The successful integration of AI into education systems and processes will require careful consideration and strategic implementation. The latest in a series of analyses on Education 4.0, this paper provides insight into AI's potential to address challenges within education systems through:

– Personalized learning content and experiences, offering solutions to the challenge of catering to diverse student needs and enabling tailored educational journeys for each learner.

– Refined assessment and decision-making processes, promising more accurate evaluations and insights into student progress.

– Optimization of teacher roles through augmentation and automation of tasks, alleviating administrative burdens and empowering educators to focus more on personalized instruction and mentorship.

– Integration of AI into educational curricula, presenting an opportunity for teaching both with and about AI, equipping students with essential skills, discernment and knowledge for the future.

A set of illustrative case studies highlights some of the learnings thus far in this frontier field. These examples point to the need for nuanced discussions and further research to explore opportunities and challenges. By leveraging this technology judiciously, we can enhance learning outcomes, empower educators and equip students with the requisite skills for success in the dynamic landscape of the future. We invite readers to engage with the findings, and support local and global dialogue aimed at shaping a more responsive, inclusive and future-ready education system in the age of AI.

Introduction

The latest results of the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA) saw record drops in student performance on mathematics, reading and science skills,[1] even as these skills become more important than ever, particularly in an era of rapid economic, social, environmental and technological change. Outcomes for students on critical thinking, collaboration and innovation, among other skills in high demand by today's employers, are also mixed across education systems around the world. Research suggests that, if deployed appropriately, new opportunities and developments in artificial intelligence (AI) hold significant promise for enhancing the effectiveness of teachers as well as outcomes for learners, revitalizing education systems towards better preparing students for the demands of the 21st century.[2]

While early forms of AI, such as expert systems and early machine learning algorithms, have been used in the education field for over 60 years, recent advancements in AI capabilities are creating disruption within the education sector. Models such as ChatGPT, Synthesia, Dall-E2 and Bard can write essays, create images, explain complex topics and provide step-by-step guidance for solving math problems, among many other functionalities. Generative AI can mimic human logic, writing and even creativity, mirroring some human thought processes and putting into question the relevance of some of the skills, principles, formulas and processes taught in classrooms today, including basics such as writing, grammar and even logic and discourse.

The increasing adoption of AI-driven tools by students for writing assignments and completing assessments has led some educators to question the basic assumptions that classroom work accurately reflects students' cognitive processes. In response, some educators are removing AI altogether from classrooms and education amid fears of student cheating and concerns over data privacy. Others are seeking ways to appropriately embrace technology in education and cultivate critical thinkers who can understand and work alongside AI, bearing in mind changes in the nature of jobs and work in today's and tomorrow's labour markets. According to the World Economic Forum's *Future of Jobs Report 2023*, employers' top skill priorities for 2027 include cognitive skills such as analytical and creative thinking; technology skills such as AI, big data and technological literacy; and skills required for working with others, such as leadership, social influence, empathy and active listening. Additionally, many of the fastest-growing job roles are technology-related roles, necessitating digital proficiency.[3]

Education systems must adapt to prepare young people for tomorrow's technology-driven economies and to help students learn alongside these emerging technologies. The World Economic Forum refers to the teaching and learning of abilities, skills, attitudes and values that are fit for the future as "Education 4.0" (see Figure 1). Developed by a global coalition of education experts, practitioners, policy-makers and business leaders, Education 4.0 is a comprehensive framework that outlines key transformations needed in childhood education to address the needs of the future and promote better education outcomes. It consists of four sets of skills that will be needed in the future – global citizenship, innovation and creativity, technology, and interpersonal skills – as well as four sets of learning experiences – personalized and self-paced, accessible, problem-based and collaborative, and lifelong and student-driven learning. Teaching and learning that incorporates technology, particularly AI, can not only help students achieve better outcomes on technology skills but can also facilitate and enable success in other areas within the framework.

FIGURE 1 | Education 4.0 Framework

Content (built-in mechanisms for skills adaptation)

Global citizenship skills
To include content that focuses on building awareness about the wider world, sustainability and playing an active role in the global community.

Innovation and creativity skills
To include content that fosters skills required for innovation, including complex problem-solving, analytical thinking, creativity and system-analysis.

Technology skills
To include content that is based on developing digital skills, including programming, digital responsibility and the use of technology.

Interpersonal skills
To include content that focuses on interpersonal emotional intelligence (i.e. empathy, cooperation, negotiation, leadership and social awareness).

Experiences (leveraging innovative pedagogies)

Personalized and self-paced learning
From a system where learning is standardized, to one based on the diverse individual needs of each learner, and flexible enough to enable each learner to progress at their own pace.

Accessible and inclusive learning
From a system where learning is confined to those with access to school buildings to one in which everyone has access in learning and is therefore inclusive.

Problem-based and collaborative learning
From process-based to project and problem-based content delivery, requiring peer collaboration and more closely mirroring the future of work.

Lifelong and student-driven learning
From a system where learning and skilling decrease over one's lifespan to one where everyone continuously improves on existing skills and acquires new ones based on their individual needs.

Source
World Economic Forum.

This paper is the first in a World Economic Forum series on education and AI and sets out to consider specific areas where AI may enable Education 4.0 and showcases practical examples that can serve as inspiration for global leaders and practitioners.

The first chapter frames the context for the potential use of AI in education by identifying key challenges that are contributing to declining student performance: the global teacher gap, gaps in administrative and assessment processes, and the global digital skills gap. The second chapter explores the promise of AI in education – in optimizing teacher roles, supporting decision-making and management, advancing personalized learning experiences, and integrating AI into educational curricula. The third chapter presents case studies that have been collected in collaboration with the Education 4.0 Alliance to spotlight the intersection of education and AI and offer practical guidance on how new AI technologies are beginning to be leveraged in education systems today. The paper concludes with a brief reflection on the investments and policy efforts required to maximize opportunities and minimize risks, as well as the next set of activities and initiatives that are expected to emerge from the World Economic Forum's Education 4.0 Alliance in 2024-2025.

1 Global education systems at a crossroads

This chapter introduces three key challenges faced by the education sector that may be addressed through greater integration of technology, including AI. First, the global shortage of teachers presents a significant obstacle to improving education outcomes and the demand for educators is only expected to grow in the upcoming years. Second, teachers spend significant time on administrative tasks, impacting the time they do have to focus on quality interactions with students. Third, most education systems are lagging in closing the digital skills gap – a critical factor in ensuring the future employability of students as well as in developing in the next generation the necessary aptitude and ethical awareness for the responsible development and deployment of emerging technologies.

1.1 Global teacher gap

The United Nations Educational, Scientific and Cultural Organization (UNESCO) projects that an additional 44 million teachers will be needed by 2030 to fulfil the ambitious targets set forth by Sustainable Development Goal (SDG) 4, which aims to ensure inclusive and equitable education and promote lifelong learning opportunities for all.[4] This acute and growing teacher gap is affecting both developed and developing economies. However, the shortage is particularly acute in Sub-Saharan Africa, where an additional 15 million teachers will be needed to provide universal childhood education by 2030.[5]

This need is set to grow as global labour markets face disruption, and the need for reskilling, upskilling and lifelong education grows. According to the World Economic Forum's *Future of Jobs Report 2023* one-quarter of all jobs face transformation – both decline and growth – in the next five years and on average over 40% of the core skills required in all jobs are expected to change during that period. As such, the report predicts a growing demand for education-related roles, including Vocational Education Teachers, Special Education Teachers, and University and Higher Education Teachers, all among the top 10 positions with the largest projected increase in employment.

Education systems compete with various sectors of the economy to attract top-tier graduates into teaching roles. Studies show that offering competitive salaries is crucial for both retaining teachers and attracting new individuals to the profession. Yet, in many OECD countries teaching is not a financially attractive career choice. On average, lower secondary (typically, the first three years immediately following primary education
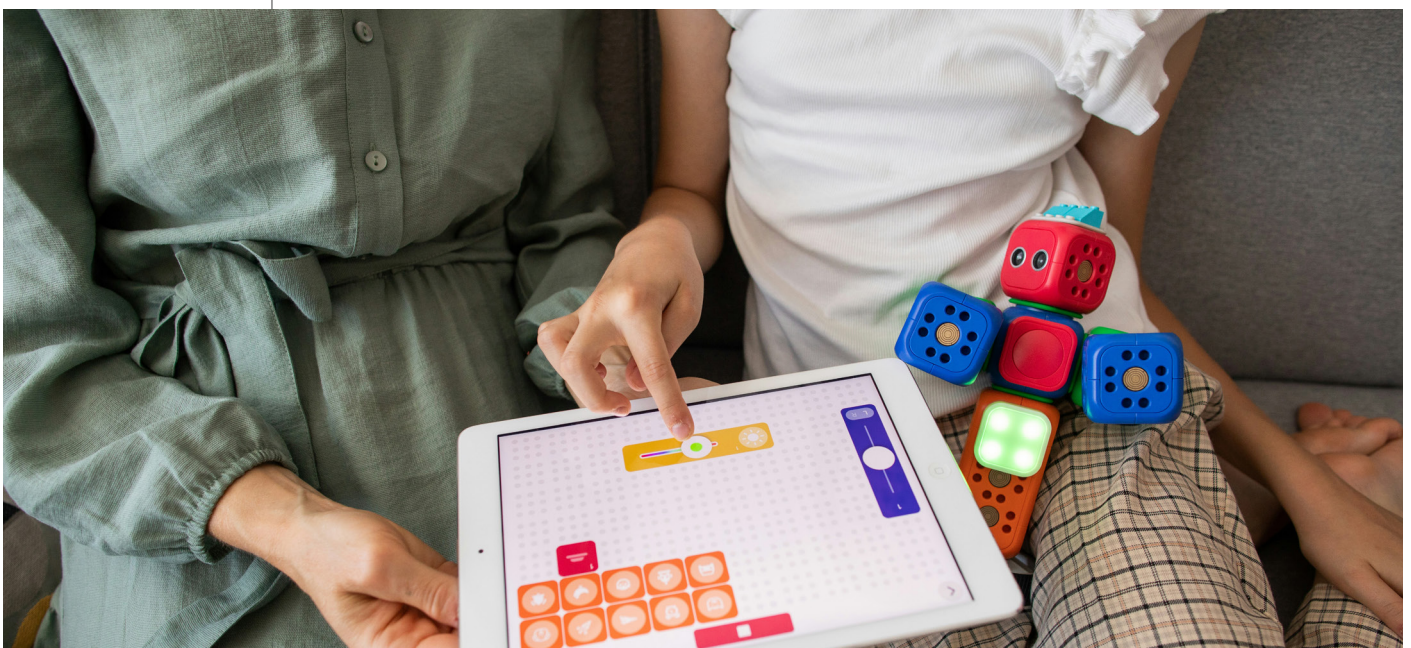
and which in many countries ends compulsory education) teachers' salaries lag behind those of tertiary-education workers by 10%; in some countries, the gap is over 30%.[6,7]

A significant set of work will need to be done by governments and other stakeholders to ensure that a robust set of new talent joins the future teaching workforce, that teachers are adequately remunerated, and that teaching is positioned as a high-growth, high-potential job of the future. There is an opportunity for AI and other emerging technologies to help address these goals, by supporting those already in the teaching workforce and ensuring that teaching emerges as a "future-ready" profession. While technology will never fully replace human teachers, AI and other emerging technologies can immediately address some of this gap. Many teachers already acknowledge the benefits of such support. For instance, in the United Kingdom, 42% of primary and secondary teachers used generative AI to aid with their schoolwork in November 2023, a significant increase from 17% in April 2023.[8] Alongside new incentives and structural frameworks aimed at developing, attracting and retaining talent within the education sector, governments, business and civil society can support the integration of AI as a tool for today's teachers and as an attractive additional skill set for prospective future teachers.

1.2 | Administrative and assessment gaps

The scarcity of teachers is compounded by the administrative burdens they face in the workforce. A recent survey of teachers in the United States found that while they work an average of 54 hours per week, only 46% of that time is spent teaching. Similarly, when looking across OECD countries, lower secondary school teachers spend an average of about 44% of their working time on teaching and the rest of their time on non-teaching tasks.[9] The burden of repetitive administrative tasks is regularly cited by teachers and school leaders as one of the leading aspects affecting the quality of jobs in the education sector. In the latest OCED Teaching and Learning International Survey, the main source of stress for teachers in both primary and lower secondary education has been "having too much administrative work to do", at 47% and 48%, respectively.[10]

Addressing these pain points expressed by teachers and school leaders by automating administrative tasks and augmenting human-centric ones could help free up time that teachers can spend on higher value tasks – such as directly engaging with students, customizing content for maximum impact or developing their own pedagogical skills. Alleviating this burden can improve the attractiveness of the sector, which could in turn help mitigate the global teacher shortage noted in the previous section.

Inefficient assessment processes also hinder the ability of education leaders at the district, national and global levels to make timely and data-driven decisions when it comes to their education strategies and investments. For example, while education systems aim to regularly assess student understanding throughout the school year, comprehensive evaluations that are comparable across schools occur infrequently. Learner performance is typically evaluated sporadically by schools and only annually by Ministries of Education during curriculum review. Meanwhile, cross-country comparisons, such as those conducted through the OECD's Programme for International Student Assessment (PISA), take place every three years. This lack of frequent data on student learning outcomes and skills gaps prevents education systems from having the agility required to adapt to changing learning and labour-market needs.

Integrating AI technologies into educational assessments offers the potential for educators to gain real-time, data-driven insights into student learning trends, identifying areas of strength and weakness and assessing instructional effectiveness on a large scale. It also helps in evaluating non-standard tests more efficiently, informing instructional decision-making and curriculum development, and enhancing the overall quality of education delivery.

1.3 | Digital skills gaps

Generative AI has the potential to create trillions of dollars in economic value, driven by increases in labour productivity and the creation of new revenue streams from product innovation.[11] However, such estimates rely on the assumption that individuals, teams and organizations will have the ability and willingness to use AI and other technology tools effectively.

While the potential economic benefits of generative AI and other emerging technologies are promising, unlocking this value hinges on addressing the most significant barriers: persistent global shortages in digital skills and AI talent. The current labour market is already experiencing significant shortages of workers with expertise in AI technology and this demand is poised to escalate further. A recent survey shows that 68% of executives report a moderate-to-extreme AI skills gap.[12] Furthermore, advances in AI development are slowing due to a global shortage of talent with skills in areas such as deep learning, natural language processing and robotic process automation.[13]

However, AI can also lead to job displacement by automating the majority of tasks in some roles. Those lacking technological literacy are most at risk of displacement, while those up are able to reskill and upskill in a variety of skills – including becoming proficient in using, developing, explaining or applying AI – are most likely to make successful job transitions.[14] To prepare workers and address global digital and skills shortages in the medium-to-long term, teaching about technology, including AI, must be emphasized in education.

These future-ready digital skills should also include education about the use of new technologies as well as how to be safe and ethical producers and consumers of technology. Young developers need to understand the ethical considerations when designing AI and must develop a keen awareness of the potential risks and implications of AI design and deployment.
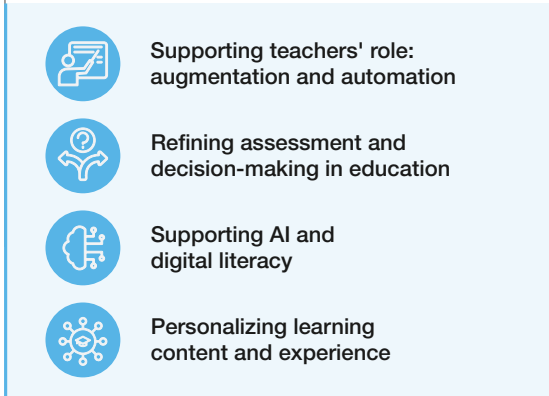
2 Potential of AI in enabling Education 4.0

This chapter explores the potential ways in which AI can address the gaps highlighted in the previous chapter.

FIGURE 2 | **4 Promises of AI in education**

- Supporting teachers' role: augmentation and automation
- Refining assessment and decision-making in education
- Supporting AI and digital literacy
- Personalizing learning content and experience

First, integrating AI into education presents an opportunity to streamline a broad set of administrative tasks for teachers, allowing them to dedicate more time to engage with students. Second, AI can help teachers in assessing learners more rapidly and enabling them to provide more immediate feedback. Third, AI can enable students and learners to develop digital literacy, critical thinking, problem-solving and creativity skills. Finally, AI can personalize the learning experience, supported by teachers, leading to improved academic performance and better adaptation to diverse learning needs. Across all four opportunity areas, AI is a complementary tool that enhances the educational experience, while preserving the essential human elements embedded in teaching and learning. In addition, learning about AI and digital skills – even through traditional methods – can support learners in being prepared for the jobs of tomorrow.

2.1 | Supporting teachers' roles through augmentation and automation

New developments in AI can provide an opportunity to redefine the nature and quality of work in education roles. Research by the World Economic Forum, produced in collaboration with Accenture,[15] finds that 40% of all time spent on tasks could potentially be impacted by large language models (LLMs). This applies to teaching as well: while some teaching tasks could potentially be automated by these new technologies, other tasks stand to be augmented or enhanced by LLMs (see Table 1).

Tasks with the most potential to be automated or replaced by LLMs are those that tend to be routine or repetitive. In the education sector, up to 20% of work time on clerical activities and administrative tasks, such as assessing attendance, enrolment and other forms of data analysis, could be automated. Tasks most likely to benefit from the augmentation potential of LLMs tend to emphasize analytical and problem-solving capacities. These tasks make up 8%-20% of work time spent on tasks in the education sector and include lesson planning and evaluating student performance.

| TABLE 1	Impact of large language models (LLMs) on education tasks
Automatable tasks	– Compile lists of books, periodicals, articles and audio-visual materials on particular subjects. – Verify facts, dates and statistics, using standard reference sources. – Grade homework and tests, and compute and record results, using answer sheets or electronic marking devices.
Augmentable tasks	– Analyse performance data to determine effectiveness of instructional systems, courses or instructional materials. – Design learning products, including Web-based aids or electronic performance support systems. – Develop teaching or training materials, such as handouts, study materials or quizzes. – Prepare assignments for teacher assistants or volunteers.
Lower potential for exposure and unaffected tasks	– Establish clear objectives for all lessons, units and projects and communicate those objectives to children. – Confer with leaders of government and community groups to coordinate student training or to find opportunities for students to fulfil curriculum requirements. – Collaborate with other teachers and administrators in the development, evaluation and revision of elementary school programmes. – Plan and supervise class projects, field trips, visits by guest speakers or other experiential activities, and guide students in learning from those activities. – Set up classrooms, facilities, educational materials or equipment.

Source

World Economic Forum, in collaboration with Accenture, 2023.

Tasks that emphasize interpersonal interactions, like face-to-face communication or physical interactions with young learners, are likely to be unaffected or not enabled by LLMs, and most teaching tasks – and roles – feature prominently in this category of jobs that are likely to be unaffected by AI (see Figure 3).

Taken together, the automation and augmentation potential of LLMs for routine and repetitive administrative work in teaching opens up more time for educators to focus on creative tasks such as curriculum design and, of course, the essential educational aspects of interpersonal interaction. However, such a transformation would need to be carefully designed and enabled to ensure that teachers are able to manage the pace of automation or augmentation and be supported in their own upskilling, while they learn to focus on the more human-centric aspects of their jobs, such as refining their pedagogy, providing social-emotional support, individualized instruction and parent engagement.

FIGURE 3 | Potential for automation and augmentation of education jobs

	Higher potential for automation	Higher potential for augmentation	Lower potential for automation or augmentation	Non-language
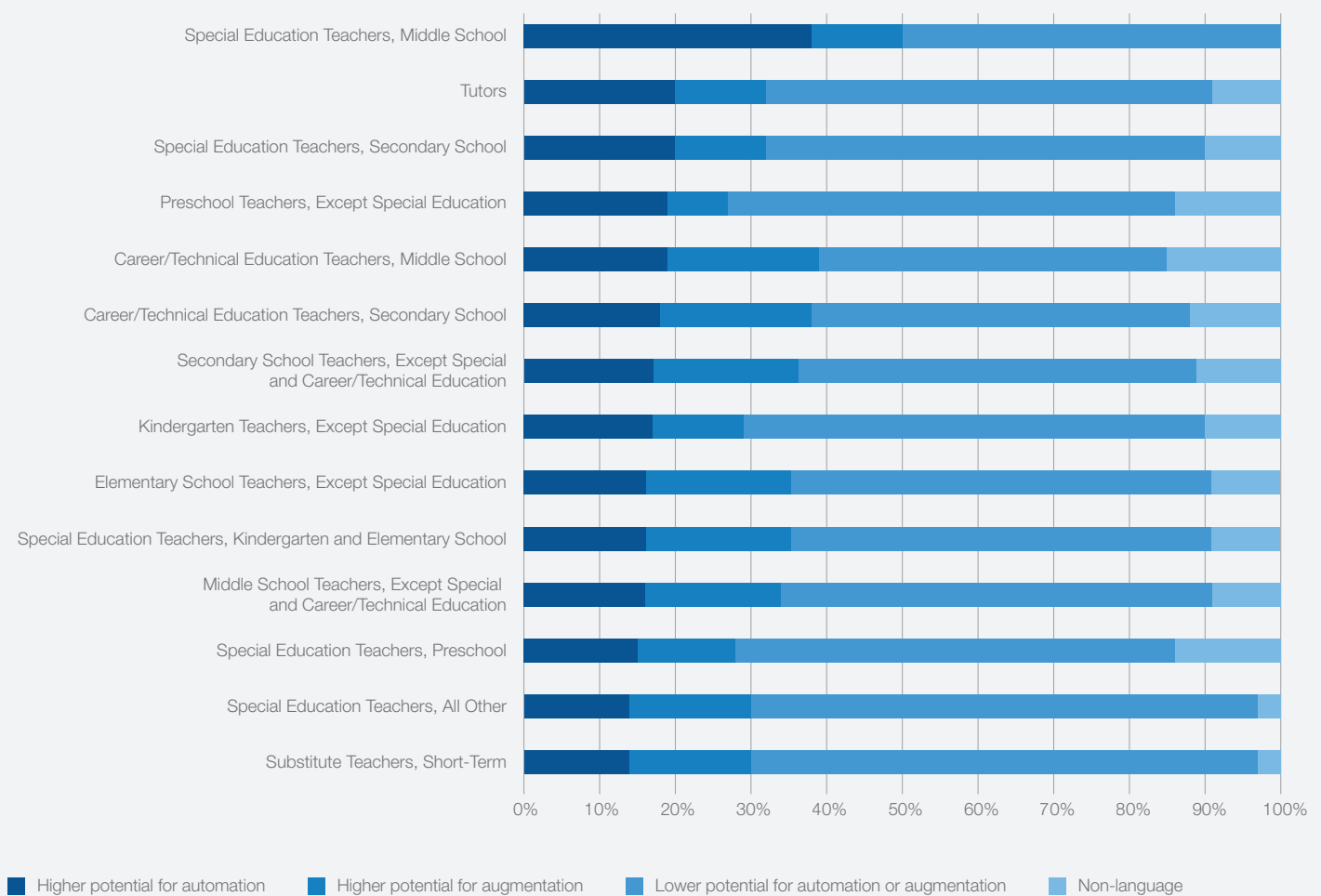
Source

World Economic Forum, in collaboration with Accenture, 2023.

2.2 | Refining assessment and analytics in education

Today's models of standardized and informal assessment often exhibit linear and time-consuming characteristics, as discussed in the first chapter. Similar to how human tutors can offer instant, personalized feedback, AI automation in assessments can allow for immediate feedback on a larger scale, aiding students in comprehending mistakes and supporting teachers in identifying areas for improvement.

However, such analytics are best enabled in partnership with teachers. AI tools can be programmed with the support of teachers who can provide examples of feedback for AI to learn from, including in evaluating non-test assignments such as essays, project proposals and similar tasks.

Furthermore, the adoption of game-based assessment technologies can alleviate pressure on

both teachers and students by eliminating the need to conduct one-off, high-stakes exams. Through automated, regular feedback mechanisms, students can engage in meaningful, enjoyable learning activities where all learning is analysed in real-time, rather than relying on periodic formal assessments. This shift from traditional assessment methods to dynamic, real-time analytics has the potential to significantly enhance the educational experience, fostering adaptive learning environments that cater to the diverse needs of students.

Machine learning and AI-powered analytics can enable education systems to be more agile and responsive to immediate learner needs. All stakeholders – including students, teachers, parents, school leaders and ministries – can receive timely analytics for informed and adaptive decision-making, fundamentally transforming current

linear and time-lagged approaches to learning assessment into future-ready, responsive and dynamic models. Big data sets can be analysed not only for correct or incorrect answers, but also for understanding larger patterns within and across education systems as well as predicting where future gaps may emerge across cities and regions.
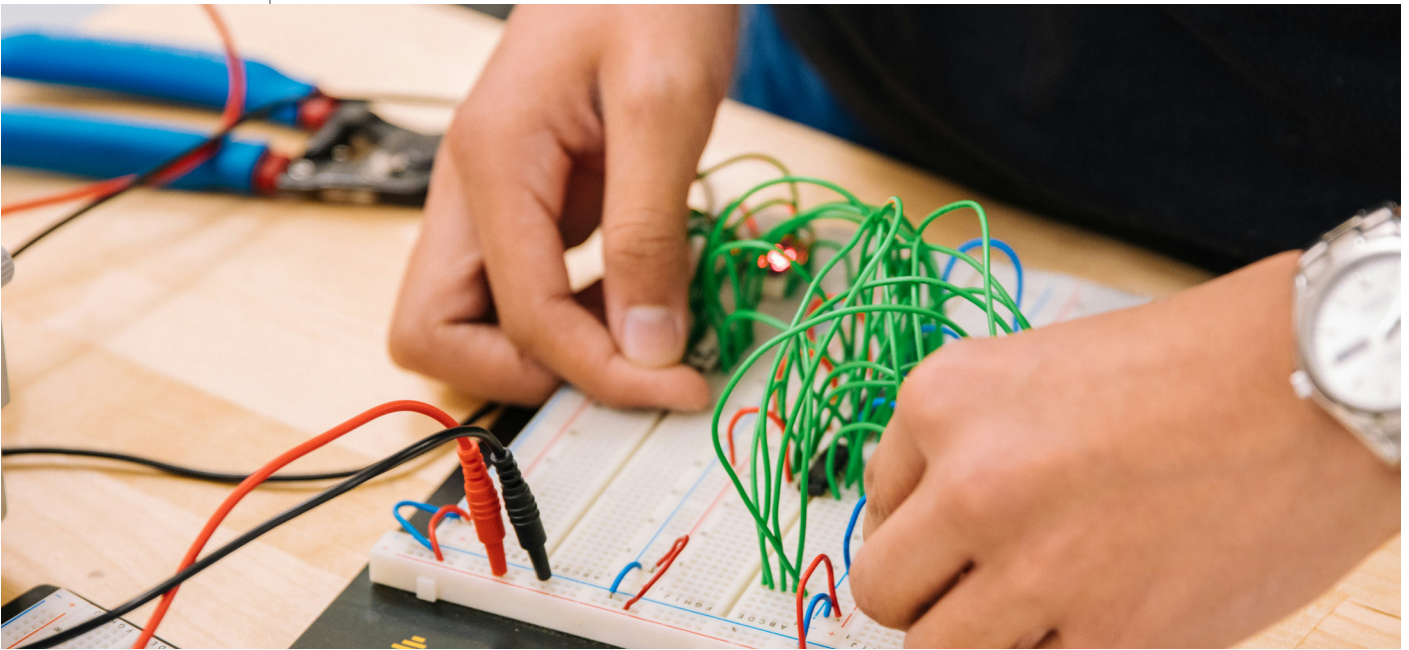
2.3 | Supporting AI and digital literacy

Developing digital skills is essential for navigating today's technological landscape and lays the groundwork for both AI and digital literacy. Digital and AI literacy goes beyond the mere ability to use digital tools and platforms; it also encompasses critical thinking, problem-solving, creativity and awareness of the ethical implications of AI.

Integrating AI into education presents an opportunity to not only utilize AI tools in teaching but also to educate students about AI concepts and their broader societal impacts. Integrating AI into curricula does not imply that every student must become an AI expert. Rather, the emphasis should be on cultivating awareness, nurturing curiosity and establishing a foundational understanding – for example, by teaching students how to assess the reliability of sources and discern the accuracy of information presented on websites. One study found that digital literacy is indeed a good predictor of one's ability to distinguish between facts and misinformation.[16] This is a particularly important and urgent life skill as more people than ever in history will vote in 64 national elections in 2024 –

representing about 49% of the world's population.[17] Teaching about AI not only equips students with the ability to recognize disinformation and misinformation but also fosters their development into responsible future AI developers. Moreover, incorporating basic cyber skills into curriculum can help students learn how to build robust and safe AI systems. Safeguarding the security and integrity of AI data systems is imperative, particularly in light of the potential risks associated with data breaches, hacking and malicious manipulation of AI algorithms.

Enhancing the integration of AI applications into education systems globally can give the technology a pivotal role in educating students about responsible and equitable AI practices. Resources already exist for teaching about AI, such as the International Society for Technology in Education (ISTE) "Hands-on AI Projects for the Classroom", which includes specific projects that teach concepts such as unconscious bias and active vs. passive data collection, and terms such as machine learning algorithm and targeted marketing.[18]

Some economies have started to lay out basic principles for how to integrate AI and digital literacy into classrooms. In the United Kingdom, for example, the Office for AI is currently conducting research to support primary and secondary schools to teach critical skills such as the limitations, reliability and potential bias of generative AI; how information on the internet is organized and ranked; and foundational knowledge about how computers work, connect with each other, follow rules and process data.[19] Australia, Japan and New Zealand have also outlined guidance around teaching with and about AI.

Encouraging digital and AI literacy among learners equips them with valuable skills for navigating the increasingly AI-driven aspects of tomorrow's job market, providing them with a competitive edge and greater versatility in their career paths.

2.4 | Personalizing learning content and experiences

A study by education psychologist Benjamin Bloom found that the combination of one-to-one tutoring alongside regular tests and feedback led to student performance that was two standard deviations – about 98% – above those of students who receive standard classroom instruction.[20] The research concluded that "there is a great difference in student cognitive achievements, attitudes, and academic self-concept under individual tutoring compared with the group method of instruction". Providing personal tutoring dramatically changed the distribution of education achievements in the class. A more recent study by Stanford University researchers found that even short tutoring interventions, as brief as 10 minutes a day, result in significant improvement in young student's literacy skills.[21]

However, scaling personal tutoring methodology is costly and inefficient in even the most advanced economies. It would require a significant change in teacher-pupil ratios, which is challenging if not unrealistic, given existing global teacher shortages. While private tutoring is well recognized for its impact on student performance, and the global private tutoring market is projected to grow from $57.92 billion in 2023 to $105.98 billion by 2030, access is generally restricted to those who can afford it, further perpetuating inequalities in learning outcomes.[22]

Since the rise of personal computing and digitalization, there has been growing interest in using technology to accelerate personalized learning.[23] A study conducted between 2007 and 2020 found that technology-supported personalized learning had a significant positive effect on learning outcomes.[24] While technology has thus far not been able to fully replicate the benefits of one-to-one tutoring, recent advances in AI are able to analyse and learn from big data sets, providing tailored learning content, experiences and real-time feedback, much in the same way that a private tutor would.

Algorithms can not only customize the content but also adjust the pace, difficulty and learning style depending on learner performance, behaviour and preferences.[25] Based on data patterns, AI can predict learning challenges, identify gaps and create personalized learning journeys by analysing trend data and students' learning history, preferences and performance. AI can provide materials that match students' strengths, weaknesses and knowledge levels, and align with learning objectives, thereby enhancing the relevance of the educational content for each individual learner.

However, these new tools are best enabled when complemented by rigorous stress-testing processes by teachers in personalizing support, tailoring culturally relevant teaching and learning materials, and providing instant translation to adapt content to learner needs. The relevance of the materials and examples is essential for creating an engaging, understandable and applicable learning environment for learners – and AI tools, together with teachers, can relate examples and concepts to each student's interests, lived experiences and backgrounds.

Finally, AI can also present materials in various modalities to address different visual, audial and physical needs. Customizable interfaces and adaptive technologies are particularly valuable for neurodiverse students and those with varying physical abilities. For example, through AI technology, classroom lessons can be captioned for students who have auditory impairments, allowing them access to any classroom rather than relying on the availability of human sign language assistants; this helps teachers and learners engage in faster and more personalized communication.

3 Emerging examples of how AI is advancing Education 4.0

The integration of the latest AI tools in education is a relatively new development, which needs careful management and monitoring of results. The case studies presented in this chapter offer practical guidance on how AI technologies are being leveraged in education systems today. While the selected case studies do not represent a comprehensive overview of all innovative and impactful examples, they showcase the transformative potential of AI-driven innovations and inspire educators, policy-makers and businesses to embrace the opportunities and calibrate risks and challenges.

3.1 Selection process and criteria

The World Economic Forum's Education 4.0 Alliance – made up of leaders, experts and decision-makers in education – aims to identify policies, initiatives and programmes that advance the Education 4.0 framework. In 2023, the Alliance developed a set of criteria to identify emerging examples of how AI tools are being leveraged to advance Education 4.0 in the absence of global standards and comprehensive policies. These criteria include:

– **Significance**: magnitude, reach and transformative nature of the impact

– **Quantifiability**: use of metrics to measure and drive further impact

– **Scalability**: future impact potential beyond the current reach and applicability in different contexts

– **Sustainability**: sustainability of the initiative and potential for long-term impact

Recognizing the potential that AI may have to exacerbate current education gaps, all selected case studies strongly emphasize education equity in their design. Following a call for submissions through its various partner networks, the World Economic Forum's Centre for the New Economy and Society and the Alliance, with the assistance of a panel of independent experts, selected nine case studies relating to the gaps and opportunities identified earlier in this paper and based on the evaluation criteria.
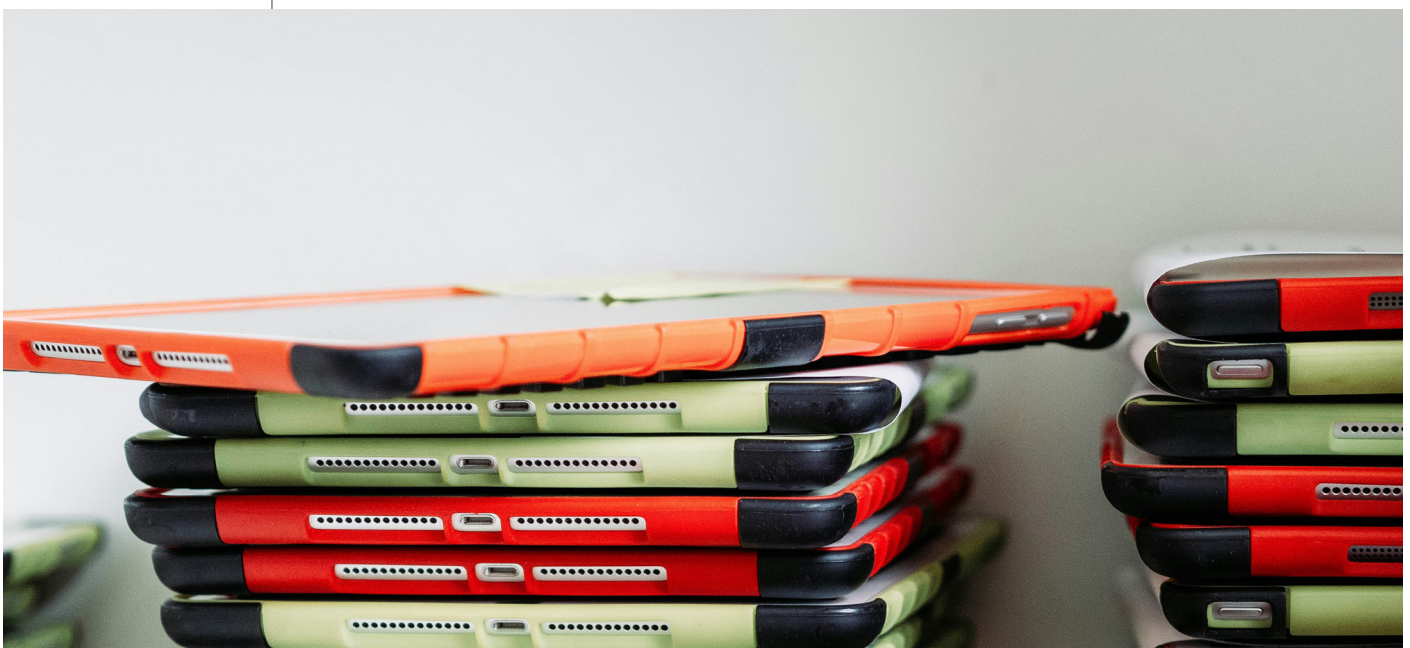
3.2 | Case studies

Accessible Digital Textbooks (ADT)
UNICEF

The initiative employs Universal Design for Learning (UDL) principles and accessible technology to create digital tools that cater to diverse learners, including those with disabilities.

Context and objectives

Of the 240 million children globally who have disabilities, the vast majority lack access to inclusive technologies, easily accessible learning materials and other vital educational support to fully engage and participate in their learning endeavours. Half of children with a disability are out of school and one billion children and adults with disabilities need assistive technology but do not have access to it. Managed by UNICEF, the Accessible Digital Textbooks (ADT) initiative employs UDL principles and accessible technology to create customizable, inclusive digital tools for diverse learners, including those with disabilities. UNICEF plans to leverage AI for cost-effective scaling, collaborating with partners globally to transform education for children with disabilities, and expanding the initiative to new regions. A co-creation approach involving local stakeholders enhances the ADT ecosystem, contributing to improved learning outcomes and reimagining the future of textbooks. ADTs have been implemented in three countries in the Eastern and Southern Africa regions, and six countries in Latin America and the Caribbean, in coordination with the respective Ministries of Education, with a goal to reach 500,000 children in the first half of 2024.

AI-enabled aspects

UNICEF aims to revolutionize textbooks using AI for widespread implementation. ADTs allow users to customize and combine diverse features like narration, sign-language videos, interactivity, the audio description of images, text-to-speech and other functions to suit different preferences or access needs. Once installed, the learner can use the textbook offline on the device, making it accessible to students who lack connectivity, promoting education that is personalized, inclusive and accessible

Expected impact

Research and development conducted by UNICEF and its partners indicate that ADTs can enhance students' motivation, classroom participation and their ability to engage with one another.

CASE STUDY 2

Skill-building with Virtual Mentors
Kabakoo Academies

An educational technology start-up in West Africa pioneering a transformative approach to upskilling young people in the face of limited formal job opportunities.

Context and objectives

Over 80% of employment in Africa is informal, impacting the opportunities available to the continent's young talent. Kabakoo is an educational technology start-up with a mission to enable young people in West Africa to develop the mindset and skills for self-employment in a setting that lacks formal jobs. They have developed a community-driven upskilling approach that combines a mobile application with real-life networks of peers and mentors. Kabakoo leverages social media content and local partnerships to engage youth in urban and semi-urban areas of West Africa. The Kabakoo app provides community-based experiential learning, enriched by modules on learning to learn and visualization and with the support of an LLM-based virtual mentor. Furthermore, Kabakoo fosters real-life community interactions to support the acquisition of digital and entrepreneurial skills

AI-enabled aspects

Kabakoo employs an AI-enabled virtual mentor to provide 24/7 support to learners. This virtual mentor offers guidance, resources and advice whenever needed, supplementing human mentorship. The AI mentor also provides personalized feedback on learners' assignments. After submitting their selfie video on a specific module, learners receive a personalized response via WhatsApp. Recognizing the linguistic diversity in Mali, Kabakoo is working on developing an AI-powered model to provide training in Bambara, the most spoken language in the country. In applying AI to address language barriers, Kabakoo promotes personalization, accessibility and inclusivity. The use of gamified virtual tokens (Kabakooins) and cloud-based resources contributes to a dynamic and robust learning environment.

Expected impact

The success of the programme is evidenced by a randomized control trial that resulted in a 23% increase in growth mindset among learners in a pilot conducted at Kabakoo. Kabakoo learners also report seeing a 44% increase in income six months after completing the programme.

CASE STUDY 3

Leveraging Literacy through AI
Letrus

An AI-based literacy development initiative implemented in middle and high schools across Brazil.

Context and objectives

The latest PISA scores show performance in Brazil and Latin America below the OECD average. The Letrus Program is an AI-based literacy development initiative implemented in middle and high schools across Brazil and currently benefiting 170,000 students in 670 schools. The main objective of the programme is to narrow the literacy gap between low- and high-income students. It incorporates proprietary natural language processing AI technology to offer real-time constructive feedback in reading and writing.

AI-enabled aspects

Letrus focuses on personalized learning through AI, offering immediate feedback to students, real-time data for educators and monitoring tools for school managers. Teachers receive tailored recommendations for content and methodologies, which can be seamlessly integrated into the curriculum to nurture and enhance specific skills. This iterative process ensures a dynamic and responsive approach to literacy development, aligning closely with the evolving needs of each student as well as the entire class. School managers can monitor progress and gain immediate insights into improvement areas as well as emerging learning gaps that may benefit from targeted intervention through teacher-training initiatives or strategic adjustments to the curriculum.

Expected impact

In 2022 the programme achieved notable success in the public schools of Espirito Santo. Within five months of programme implementation, participating students achieved the second position in the national writing exams, a remarkable improvement compared to the eighth position attained by the control group. Letrus was subsequently designated as the official literacy development programme for high school students in the state. Espírito Santo emerged as the top-performing state in the writing component of the National Exam, exhibiting a performance delta five times the national average from 2021 to 2022.

CASE STUDY 4

Pensamiento Computacional e IA (Computational Thinking and AI)
Ceibal

This programme teaches computational thinking and AI in an interdisciplinary way with other areas of knowledge such as mathematics, language and science.

Context and objectives

Computational thinking is a mental process by which humans try to solve complex problems by breaking them down into smaller, more manageable parts in the way computers would. It is a foundational skill for AI development. The Ceibal Computational Thinking and Intelligence programme operates in 80% of urban public schools and 250 rural schools in Uruguay. The programme's key objective is to teach computational thinking and AI in an interdisciplinary way with other areas of knowledge such as mathematics, language and science. It also includes an active intervention to reduce the gender gap in these skills. The programme focuses on teaching students to be ethical producers and knowledgeable consumers of AI, covering topics such as how a machine learning model works, how data is used and analysed, and the biases that may exist.

AI-enabled aspects

AI lessons are utilized to help students understand the inner workings of machine learning models and gain insights into the use of data, as well as the potential biases present. The programme employs various evaluation tools, including learning tests, surveys and class observations. The programme's aim is to foster the competencies of solving computational problems, data and information analysis, algorithms and procedures, as well as social transformation, acknowledging the integration of computers into our everyday lives.

Expected impact

Ceibal participates in the Bebras Competition, an international exam on computational thinking. A recent sample of Bebras exam results showed that students who participated in the programme significantly outperformed those who did not, with some differences observed in favour of girls. This community-driven initiative led to the integration of computational thinking competence into Uruguay's 2023 educational reforms.

The School Cyber Security Challenges / Cyber Skills Aotearoa
Grok Academy

An initiative aimed at providing resources for teachers to teach cybersecurity concepts and inform students about career opportunities in the field.

Context and objectives

Grok Academy is a not-for-profit Australian organization that supports the teaching of computing science and related disciplines. The organization has an extensive track record of creating student-centred and curriculum-aligned materials for cybersecurity and digital technology targeted to primary and secondary school students and teachers. In 2019, Grok Academy launched the Australian Schools Cyber Security Challenges programme, an initiative aimed at providing resources for teachers to teach cybersecurity concepts and inform students about career opportunities in the field. Developed in collaboration with government and industry organizations, the programme includes course curricula and classroom activities targeting students in years 5-12. Its success in Australia prompted expansion into New Zealand, leading to the introduction of Cyber Skills Aotearoa in October 2022. With courses, competitions and unplugged resources (ones that don't include digital devices), it engages over 91,000 students. Grok Academy's strategy emphasizes industry and government collaboration, reaching thousands across Australia and New Zealand.

AI-enabled aspects

As generative AI – which is based on large amounts of data – continues to develop, cybersecurity skills will become increasingly important. By teaching about cybersecurity, which encompasses information privacy and security, cryptography and digital forensics, Grok Academy is preparing the next generation of talent to be responsible producers of AI. There is also a clear understanding of the benefits of the programme in terms of educating the broader family community of participating students, since for many families this will be their only exposure to cybersecurity and misinformation concepts.

Expected impact

Over 4.5 million students have been introduced to cybersecurity skills since the launch of Grok Academy. While roughly half of all participants are girls, female participation exceeds male participation in years 4, 7 and 8, helping to close persisting gender gaps in cybersecurity.

CASE STUDY 6

3D Africa for Girls
Youth for Technology Foundation

A unique programme that encourages girls aged 10-16 years to develop innovative STEM-based solutions to real-world problems.

Context and objectives

Digital manufacturing and 3D printing have the potential to revolutionize Africa's manufacturing industry in the same way that smartphones and mobile broadband are transforming the service, trade and agricultural industries. 3D Africa for Girls aims to transform the continent from "Aid to Africa" to "Made in Africa". It provides high-quality STEM education in Nigeria that enables young girls ages 10-18 to design, prototype, market and sell their 3D-printed products and solutions. By doing so, it teaches and models girls to develop innovative STEM-based solutions to real-world problems, and teaches marginalized, low-income youth, girls and women how to sell those products in global, online markets. The programme leverages a combination of targeted job-shadowing and mentoring, and 3D Design and prototyping.

AI-enabled aspects

The programme's unique approach integrates 3D printing skills, real-world experts, mentors and global online marketplaces. Girls express their creativity using computer-aided design (CAD) to turn their ideas into new products (such as 3D printed rechargeable, detachable, cordless hair dryers and African-designed furniture) and market their goods. In addition to 3D design and printing, the programme also emphasizes programming skills, which are the backbone of any career in AI. Recognizing the persistent gender gap in AI careers (only 30% of the global AI workforce is female), the programme introduces young girls to the fundamentals of programming through tools such as Scratch and Bootstrap.

Expected impact

The programme has been instrumental in addressing the lack of encouragement for girls' interest in STEM subjects, with at least 90% of graduates enrolling in university or tertiary institutions one year after completion and over 85% continuing in STEM or technology careers afterwards. Within the programme, at least 90% of participants attain a minimum of 95% proficiency in basic and advanced technology skills.

CASE STUDY 7

AI for Youth Entrepreneurship Curriculum
JA Europe

An innovative curriculum blending AI and entrepreneurship education for youth.

Context and objectives

The curriculum enables youth to develop a foundational understanding of AI, including ethics, data literacy and operations. Equipped with this foundational knowledge and practical skills, participants are poised to devise economically viable solutions – leveraging AI and associated tools – that address local and global challenges. Over the long term, this curriculum aims to support a future in which all youth are AI natives. While the programme has just completed its pilot phase, JA Europe recently expanded the curriculum to 10 additional countries, which will enable it to reach 30,000 youth in the next two years, combining the application of AI with improvements to entrepreneurship and employment in the agricultural sector.

AI-enabled aspects

The curriculum focuses on preparing educators and students for a technology-driven economy, offering coding-focused and non-coding pathways to develop AI understanding, ethics, data literacy and operations. It measures efficacy through entrepreneurship competencies and tech-driven solutions. Participants engage with advanced digital skills and tools, facilitating online collaboration, ideation and the application of AI, coding and other essential tech tools in their entrepreneurial endeavours. The curriculum was developed in collaboration with dedicated Intel experts and features an interactive online computing platform for youth to develop AI-based solutions and create business plans. To ensure educational equity, JA's strategic focus lies in supporting underserved schools, especially in remote areas, and offering training to refugees, particularly from Ukraine. AI for Youth Entrepreneurship is implemented in schools selected based on their limited resources and geographical location, and in alignment with national strategies aimed at reaching underserved youth.

Expected impact

In the pilot year, student teams created 34 AI-based solutions, demonstrating the success of the programme in developing entrepreneurial capacities and understanding of AI among young people.

CASE STUDY 8

AI-Powered Digital Textbooks
Ministry of Education of South Korea

A digital textbook that enables customization for learners across various proficiency levels.

Context and objectives

The Ministry of Education in South Korea has unveiled plans to introduce AI-powered digital textbooks in local elementary and secondary schools starting in 2025. The initiative aims to meet the growing demand for diverse learning content and utilize AI and other emerging technologies to enhance the educational experience for students. This innovation in South Korea's education system aims to address educational inequality, reduce reliance on private education and transform the nation's hypercompetitive education culture. The Ministry of Education plans to continue refining the initiative, incorporating feedback and ensuring the development of diverse and creative AI digital textbooks.

AI-enabled aspects

The introduction of digital textbooks will enable customized learning opportunities for students across various proficiency levels in subjects such as mathematics, English and informatics. The programme will progressively expand to include additional grades and subjects, and eventually cover all subjects by 2028, excluding activity-based subjects like music, art, physical education and ethics. Students will receive tasks and activities differentiated based on their individual proficiency, allowing students to learn at their own pace. The Ministry of Education emphasizes the coexistence of paper and digital formats in schools. The plan also emphasizes collaboration between human teachers and AI assistants, with a focus on fostering lead teachers who provide humanized guidance alongside AI technology.

Expected impact

The Ministry of Education is currently setting up a pilot programme involving 400 teachers who will be using the AI-powered textbooks in their teacher training. The rollout of the programme is expected to begin in 2025 and will enable teachers to tailor their classes through real-time collection and analysis of data about students learning.

AI Tutor Project

Ministry of Education of the United Arab Emirates

An AI-powered virtual tutor to enhance the education landscape in the UAE and promote educational equity.

Context and objectives

The Ministry of Education of the United Arab Emirates – in collaboration with several partners, including Microsoft, ASI and teachers, among others – has developed an AI-powered tutor to enhance the education landscape in the UAE and promote equity in a context where private tutoring is on the rise. The project aims to significantly improve students' academic performance, resulting in higher test scores, better comprehension of subjects, and enhanced critical thinking skills through AI-powered personalized learning. The project employs adaptive learning algorithms, continuous assessment, 24/7 availability and data-driven insights to achieve its goals. It aims to create a more engaging and interactive learning experience, promoting self-directed learning and eliminating barriers related to time and location. While the project is in its infancy and pilot stage (the first version is scheduled to launch September 2024), the intended evidence-gathering methods for skill development include ongoing data collection, assessments and evaluations on personalized learning, critical thinking, problem-solving, self-directed learning, digital literacy and communication skills.

AI-enabled aspects

The AI tutor tailors lessons to the individual needs and learning styles of each student, ensuring that they receive the right level of challenge and support. It continually assesses student progress, identifying areas of improvement and providing targeted feedback and additional resources to help students overcome their challenges. The tutor can also provide support in multiple languages, ensuring that students from diverse linguistic backgrounds also have access to quality education. By automating certain teaching tasks and providing valuable insights into student progress, the UAE AI Tutor project aims to alleviate teacher workload, enabling them to focus on more strategic and interactive aspects of the learning experience. The platform also generates detailed reports for educators and parents, enabling them to monitor and support student progress effectively. Further, the AI tutor breaks up linear and time-consuming methods of feedback to provide real-time analytics to all stakeholders, including at the ministerial level, enabling more adaptive strategy development.

Expected impact

The project already showed improvements during the piloting stage in average grades and positive impact on students' academic performance. It demonstrated a 10% increase in learning outcomes.

Conclusion

The integration of AI technology into education presents a promising pathway for enhancing learning experiences and outcomes, while scaling AI literacy can support learners in being prepared for the jobs of tomorrow. At the same time, it is important to acknowledge the potential risks of rapid generative AI deployment in education without putting appropriate planning, safety measures, governance measures and equity frameworks in place. While AI systems often outperform similar, traditional software systems that are commonly viewed as "educational technology" or "edtech", they have attributes that may both amplify and create new risks.

Some of these concerns are widely held by parents, educators and leaders alike. A global survey of more than 17,000 people in 2023 found that 61% of respondents are either ambivalent or unwilling to trust AI systems, while 71% of people are concerned about potential risks.[26] For example, while the data collected by these tools enables their powerful results, it also leads to concerns about safeguarding student data and privacy. These concerns are linked to wider challenges around safeguards for AI. For example, a survey of over 2,300 IT professionals found that only 10% of firms had policies intended to govern the use of generative AI, while 57% are very or extremely worried about generative AI being exploited by bad actors.[27] Some concerns are held by educators themselves, around the potential of AI to disrupt teaching jobs, requiring careful management, ensuring teachers remain central to education systems complemented by AI tools, and adequate reskilling and upskilling for teachers.

Conversely, there are concerns around the potential for exacerbating inequality for those that will miss out on the benefits of AI in education. Over 2.6 billion individuals globally currently lack basic internet access.[28] It is essential, therefore, that effort and focus be oriented toward the issue of educational equity, lest the benefits of AI systems accrue primarily to geographies and communities which are already relatively privileged, further widening the education equity gap. Additionally, there are other concerns about inaction on the part of education systems in integrating a focus on AI, as synthetic content can be used to create misinformation and disinformation.[29] Children and young learners are particularly vulnerable – and a focus on AI literacy is necessary to help prepare them to critically analyse content and understand the adverse consequences of false information.

While education systems need to adapt to use AI and to teach AI literacy, it is the collaboration between human expertise and AI capabilities that holds the potential to transform learning outcomes. The case studies presented in this report underscore this element of integration as well as the need for comprehensive public-private partnerships, planning and impact assessment. Under these conditions, AI technologies can enhance teaching and learning experiences, promote equitable access to education and address pressing challenges in the educational landscape.

The case studies point to five conditions that can help balance innovation with guardrails:

–   AI for education must be developed **in collaboration with educators and education leaders**, ensuring it meets the diverse learning needs of students, supports teachers in their focus on human interactions and aids administrators in making informed decisions on relevant content.

–   AI integration in education must ensure the **protection of sensitive information** through the implementation of robust data privacy and security protocols. This includes raising awareness about ethical data use, ensuring consent, anonymizing data and limiting data collection to what is strictly necessary for educational purposes.

–   **Innovative funding models** are essential to support the ongoing refinement of AI algorithms and the creation of independent testing and evaluation of AI solutions so that stakeholders can be confident in their efficacy and value for money.

–   Students, teachers and administrators must receive necessary **training and upskilling opportunities** oriented to their needs to help them make the most productive use of AI systems.

–   **Equity and inclusion** considerations must be central to the design of programmes to ensure that AI literacy is widely imparted and the benefits of AI technologies in education accrue widely.

The next phase of research in Education 4.0 will explore these aspects and continue to develop case studies and examples of successful integration of AI tools and AI-literacy in education, working with business, government, educators and civil society to unlock the transformative potential of AI in shaping the future of education for generations to come.

Acknowledgements

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