Chapter 8
Digital Pedagogy Framework for Sustainable Education: Putting the learner at the centre

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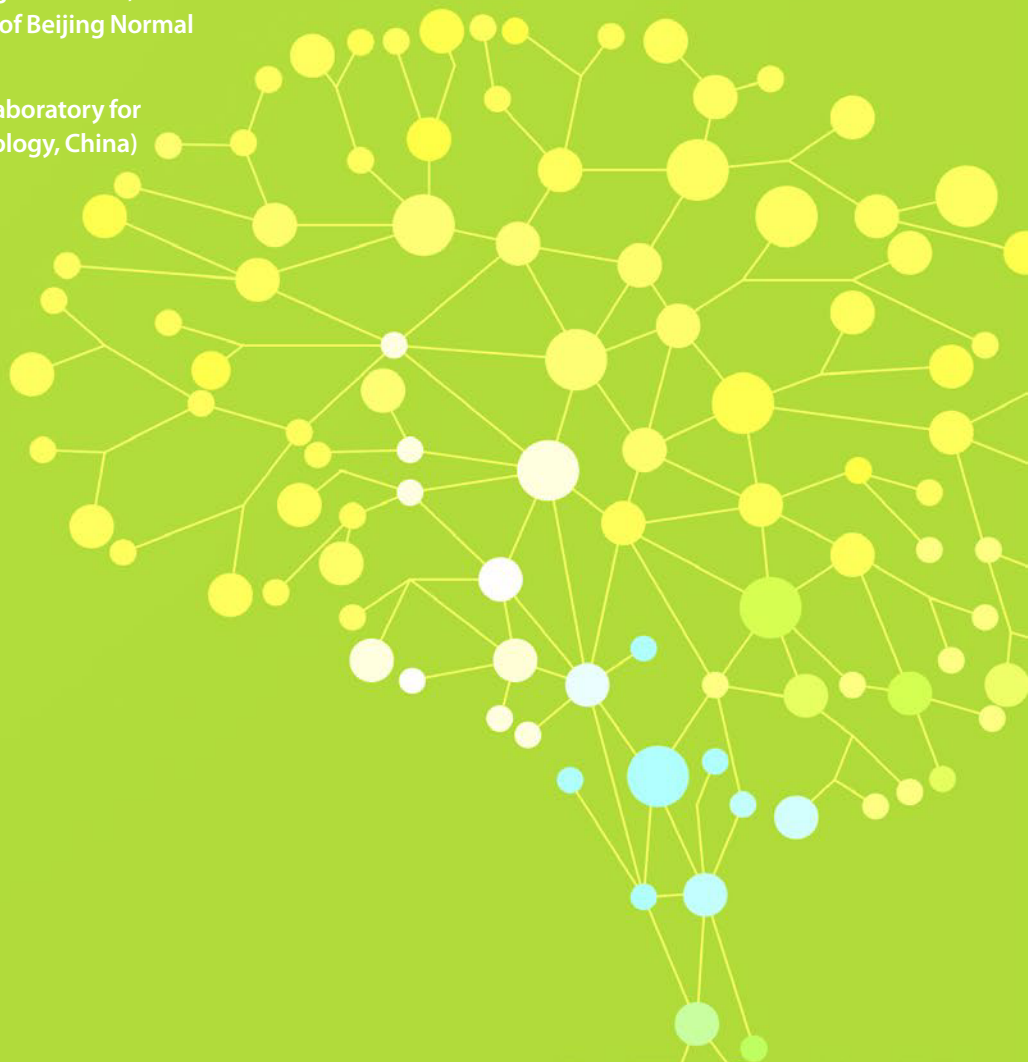


Introduction

The UN has shown commitments in promoting quality education through several initiatives as part of its overarching vision. An example is the TES in 2022, which drew attention to the global crisis in education and highlighted the need to utilize digital technologies to address the issues of access, equity, quality, and sustainability. Technology appears in six out of the ten targets of SDG 4 and was one of the main points of discussion in the five thematic action tracks of TES 2022. Technology-enhanced learning (TEL) is an effective means of supporting student learning at scale. However, are the effects of technology in education only positive? The 2023 Global Education Monitoring Report (GEMR) has revealed that while technology offers the opportunity to increase access, it can also exclude many on the wrong side of the digital divide (UNESCO, 2023a). In addition, many institutions find it difficult to keep pace with the speed at which technology is changing and lack the resources needed to implement effective teaching and learning.

Globally, society is grappling with two profound crises: an economic downturn and a learning crisis, which together pose a complex and multifaceted challenge to education systems. Nations across the world are confronting urgent educational issues, such as adapting to technological advancements, enhancing and developing teacher professional competencies, ensuring educational equity and inclusiveness, and implementing reforms to improve educational quality. During the TES in 2022, the digital transformation of education was recognized as a global consensus for addressing the learning crisis and achieving SDG 4. High-quality content, the capacity to use digital technology, and digital connectivity are emphasized as instrumental in unlocking the potential of digital learning. Quality digital learning is known to improve the cognition, metacognition, motivation, and affection dimensions of learning which are essential principles in student-centred learning (SCL) (Shehata et al., 2023).

The concept of SCL has evolved significantly over the past century, guided by diverse theories and practices. SCL refers to educational approaches that shift the focus from teacher-led instruction to learner-centred activities, emphasizing active engagement, deep understanding, and self-regulated learning (Keiler, 2018; Lee & Hannafin, 2016). It promotes an educational environment where students take ownership of their learning process by engaging in critical thinking, problem-solving, and applying knowledge in meaningful contexts (Bishop et al., 2014). In effective technology-rich learning environments, students are able to utilize technology to navigate and overcome various challenges they face in their studies. Digital tools and platforms have opened new avenues for personalized and interactive learning experiences, empowering students to take a more active role in their education.

For instance, El-Sabagh (2021) found that adaptive learning systems tailor educational content to individual student needs, promoting self-paced learning and improving engagement and can increase the motivation and academic performance of students in higher education compared to traditional teaching methods. Sailer and Homner (2020), demonstrate gamified learning environments significantly improved student engagement and knowledge retention in secondary education. However, despite these advancements, challenges remain in integrating technology to support SCL effectively. Digital divides persist, with unequal access to devices and internet connectivity hindering equitable implementation (UNESCO, 2023a). Teachers and students may also lack the necessary digital competencies to effectively integrate technology into the learning and teaching process to enhance SCL (Gudmundsdottir & Hatlevik, 2017). The limitations of technology for SCL underscore the need for a comprehensive digital pedagogy framework to facilitate the successful integration of digital technologies to support SCL activities.

This paper will first introduce two case studies that demonstrate the effectiveness of technology in enhancing self-regulated learning and promoting active learner agency, which have been shown to lead to deep learning. Based on the evidence from these cases, the Digital Pedagogy Framework for Sustainable Education Transformation (DP4SET) will be proposed to provide insights for policy-makers and educators on effectively integrating technology to support SCL.

Student-centred learning facilitates active learning, deep learning, and self-regulation

Dewey (1938) believed that education should be student-centred, and learning should be an active, social process that is grounded in experience and inquiry. Indeed, a student-centred approach has been shown to foster active learning, where students engage in tasks, discussions, and reflection to deepen their understanding (Collins & O'Brien, 2003). It also promotes deep learning, which involves grasping complex concepts by making meaningful connections between ideas (Entwistle & Peterson, 2004). Hands-on and minds-on research has consistently shown that children achieve better learning outcomes when engaged in both deep and active learning environments. For instance, Weng et al. (2023) found that active learning significantly improves creativity and critical thinking, while Wu's (2023) meta-analysis revealed that deep learning activities such as inquiry-based and project-based tasks lead to better retention and enhanced cognitive skills.

However, achieving deep and active learning in traditional educational settings presents significant challenges, including adapting teaching methods to engage all students meaningfully and maintaining sustained student motivation (Darling-Hammond et al., 2020). Research has demonstrated that technology can play a crucial role in supporting deep and active learning. For example, adaptive learning systems and AI-driven platforms provide personalized experiences and real-time feedback, facilitating deeper engagement (Liu et al., 2022).

Moreover, a core characteristic of SCL is that the learner assumes full responsibility, autonomy, and accountability for their own learning process (Singh, 2011). Recent research highlights the pivotal role of self-regulated learning (SRL) strategies – such as goal setting, self-monitoring, and strategic planning – in driving academic success (Barger & Linnenbrink-Garcia, 2018). Instruction that enhances metacognitive skills has been shown to significantly improve learning outcomes, promote effective knowledge transfer, and increase student motivation (Zepeda et al., 2019). Also, the strategic and effective use of learning resources, including digital platforms and online tools, has been strongly associated with heightened student engagement and more positive perceptions of the overall learning experience (Martin & Bolliger, 2018). In the next section, we provide evidence of various technology-enhanced learning practices in the Chinese context that laid a foundation for developing our proposed digital pedagogy framework.

Case 1. Behaviour analysis of technology usage in Chinese K-12 schools

In a technology-enhanced classroom, teachers' teaching behaviours can be categorized into six distinct types: content presentation, teacher-student interaction, classroom guidance, learning facilitation, activity organization, and resource acquisition (Zhuang et al., 2021). Aligning with John Dewey's framework of children's instincts and interests, Zhuang et al. (2021) also identified six types of technology that students may employ for learning, including exploratory technology, communication technology, construction technology, expression technology, management technology, and integrated technology.

Based on the classification of technology-enhanced classroom teaching and learning behaviours, a large-scale survey was conducted involving over 20,000 K-12 schools across China to investigate technology usage patterns among students and teachers. The survey revealed that teachers predominantly use digital tools for content delivery (56.2%), with significantly less emphasis on teacher-student interaction (17.6%) and activity organization (9.7%). Conversely, students most frequently engaged with expression technology (44.1%), communication technology (25.0%), and constructive technology (23.2%), while inquiry technology and management technology were less utilized (Zhuang et al., 2021). These findings suggest that while digital tools are integrated into classrooms, they primarily serve as aids for demonstration rather than tools for active and deep learning. Consequently, students' learning activities remain largely passive, and current teaching methods have not effectively enhanced students' inquiry abilities and comprehensive management skills. Digital technologies could integrate a suitable digital pedagogy to promote active learning in the classroom.

Huang et al. (2024) have shown that to foster active and deep learning in technology-rich environments, teaching and learning should function as a bidirectional process of empowerment. This involves implementing innovative teaching models that guide students in using technology to enhance their inquiry and self-management skills,

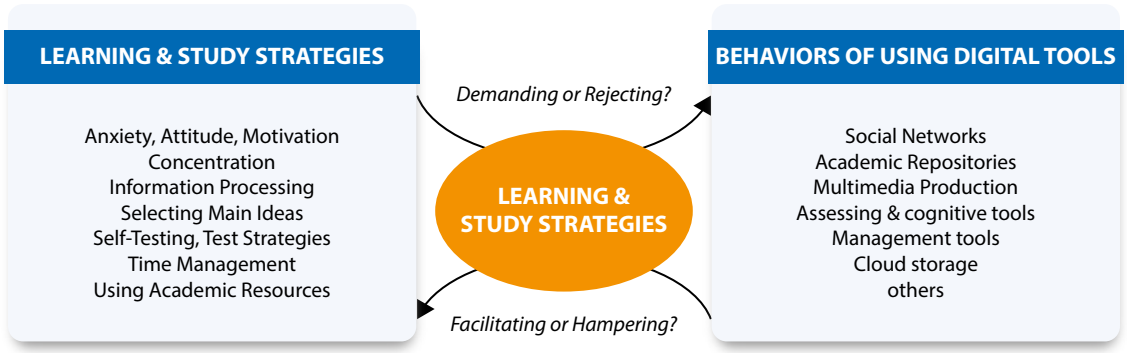
thereby promoting both active and deep learning. For example, recent studies have shown a positive influence of using generative artificial intelligence (GenAI) tools, such as ChatGPT, in heuristic teaching methods (Ruiz-Rojas et al., 2024). In our proposed framework, we show how such pedagogies could be implemented to guide students in leveraging GenAI technologies to support active learning, resulting in improved learning efficiency and outcomes.

Case 2. 15 years of Technology-Enhanced Learning (TEL) with first-year university students in China

Beijing Normal University has dedicated the past 15 years to helping first-year students adjust to university studies by providing relevant learning tools, scaffolding methods, and facilitative strategies. Utilizing the Learning and Study Strategies Inventory (LASSI) developed by Weinstein (2002), the university assessed students' awareness and use of learning strategies related to skill, will, and self-regulation. A comparative analysis was conducted with the year 2020 serving as a dividing point to mark the periods before and after the COVID-19 pandemic.

Findings indicate that in the three years following the pandemic, students demonstrated improved performance in information processing, utilization of academic resources, and motivation (see Figure 8). This enhancement is attributable to the widespread adoption of digital learning tools and online education platforms during the pandemic (Huang, 2023). The shift toward online learning environments not only increased students' sense of responsibility but also positively impacted their learning performance (Huang et al., 2023).

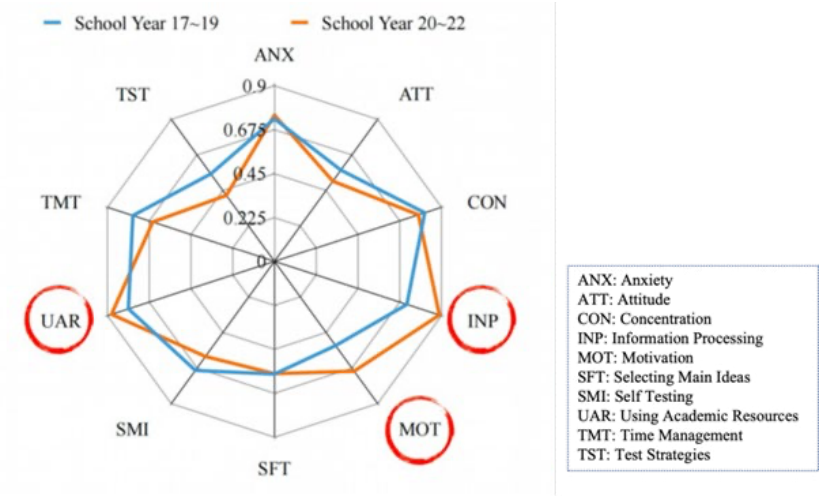
Figure 8. The impact of technology on the learning strategies of first-year university students



Source. Huang (2023).

However, the analysis also revealed that students' performance in time management, selecting main ideas, and test strategies declined in the three years after the pandemic compared to the three years before (see Figure 9). The increased reliance on online learning allowed for more independent study time but led to a reduced perception of structured learning time and fewer opportunities for face-to-face communication with instructors. This negatively affected students' ability to identify learning priorities and apply effective test strategies. Additionally, the lower psychological pressure of online exams contributed to diminished exam preparation and strategy application.

Figure 9. The 3-year comparison of LASSI scores before and after the pandemic



Source: Huang (2023).

Based on these findings, the decline in certain aspects of student performance could be addressed by establishing a structured digital learning environment that supports the development of effective learning habits. For example, providing students with high-quality digital tools – such as learning management applications, personalized learning platforms, and online simulation test platforms – could enable students to better manage their time, set learning goals, prioritize study tasks, and refine exam strategies, ultimately improving their academic outcomes.

Digital Pedagogy Framework for Sustainable Education Transformation (DP4SET)

There are many kinds of classical pedagogy in classrooms, such as Herbart's four-stage teaching theory, Dewey's five-step teaching method, and Piaget's and Vygotsky's theories. Herbartian pedagogy dealt with a clear learning process for student learning involving four stages (clearness-association-system-method), which made teaching easier to understand at the time (G. Liu & Liu, 2021). Kivelä and Siljander (2013) revealed that Herbatian ideology was used to revolutionize educational science in Finland. Dewey's five-step approach to learning (identify the problem, analyse the problem, suggest possible solutions, suggest the best possible solution, and test and implement the solution), which emphasizes 'learning by doing' aims to stimulate students' creativity and critical thinking. Lourenço (2012) adds that both Piaget's and Vygotsky's theories that focused on childhood development are essential for cognitive development.

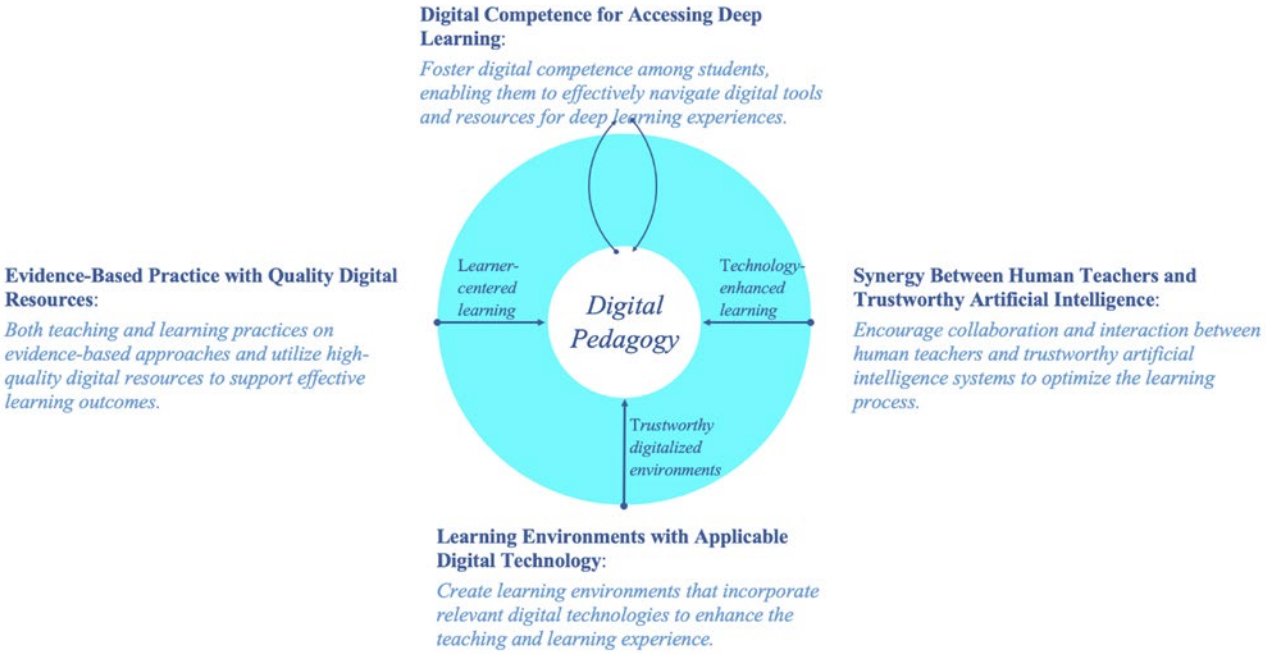
These teaching methods fundamentally focus on student agency, creating suitable teaching environments for students from various perspectives. They enhance students' learning engagement and promote improvements in learning effectiveness and efficiency. Teachers especially need to rethink and reimagine new forms of teaching powered by digital technologies in this digital age. Darling-Hammond et al., (2020) reiterated that scholars in the science of learning have emphasised that developing essential learning demands a different approach to teaching and learning compared to previous educational eras. In the past, learning was often viewed as merely acquiring facts, and teaching was seen as the linear transmission of information to be accepted and utilized without modification. For example, the Herbartian four-stage theory of learning focuses on complete instructional control over learning (Engeström & Sannino, 2012). That is, although the aforementioned classical theories have shown to improve student learning, particularly school children, modern education systems invigorated with novel technologies require a different approach to teaching and learning. The proposed digital pedagogy framework places the learner at the centre of learning and emphasises learner agency and autonomy.

Using a hand search approach of key documents on digital pedagogy and AI in education and drawing from the insights from the two case studies, we provide an update on the aforementioned classical pedagogy frameworks in contemporary educational institutions.

The proposed digital pedagogy framework, DP4SET, focuses on creating enabling learning environments with appropriate digital infrastructure, evidence-based pedagogic practice, quality digital resources and a close synergy between human teachers and AI (see Figure 10). It consists of four essential components which embody learner-centred learning, technology-enhanced learning, and trustworthy digitalized environments (see Figure 10).

The four components include: 1) digital competence for accessing deep learning, 2) evidence-based practice with quality digital resources, 3) learning environments with applicable digital technology, and 4) synergy between human teachers and trustworthy AI. Each of the four components of the proposed digital pedagogy framework is described in detail below.

Figure 10. Digital Pedagogy Framework for Sustainable Education Transformation (DP4SET)



Source: Huang et al. (2024).

Digital competence for accessing deep learning

Weng and colleagues (2023) define deep learning as the quest for higher-order competencies such as critical thinking ability, problem-solving ability and innovation ability. Research has shown that technology can promote deep learning for students in diverse educational contexts (Wu, 2023). Ferrari (2012) defines digital competence as the set of knowledge, skills, attitudes, abilities, strategies, and awareness that are required when using ICT and digital media to perform tasks, solve problems, communicate, manage information, collaborate, create and share content, and build knowledge effectively, efficiently, appropriately, critically, creatively, autonomously, flexibly, ethically, and reflectively for work, leisure, participation, learning and socializing. Digital competence also involves the safety, ethical, and social dimensions of using digital technologies (Mehrvarz et al., 2021). People with digital competence can use digital media to seek information, analyse and filter what they receive from cyberspace, and communicate with others using diverse digital tools and applications (Mehrvarz et al., 2021). In today's era of AI revolution, educational technologies like GenAI have become increasingly prevalent. As a result, learners require digital competence to effectively and safely navigate the online space and use AI-related tools (UNESCO, 2023b). The importance of gaining digital competence as integral to future educational sustainability is emphasized in several competency frameworks such as the DigComp 2.2 framework by the European Union (Vuorikari et al., 2022) and the Digital Literacy Global Framework (DLGF) by UNESCO (UNESCO-UNEVOC, 2018).

Evidence-based practice with quality digital resources

While studies show that the digital competence of students could foster deep learning, appropriate digital pedagogies are needed to facilitate this (Liu et al., 2022). Evidence-based pedagogical practices are those that show improvement in students' academic achievement, interest, and learning trajectories (Wong et al., 2023)with teachers citing insufficient preparedness and training time for new methods. To investigate potentials for online PD methods to effectively address these issues, while increasing sustainability, this study examined teachers in Title-I elementary schools spanning multiple school districts participating in a large-scale online PD certificate programme preparing teachers over 10 instructional weeks to implement Next Generation Science Standards (NGSS. However, teachers need to recognize and harness the potential of digital technology in their daily teaching practices and utilize it effectively (Spiteri & Chang Rundgren, 2020). Previous research has shown that integrating digital resources is optional even when materials are provided to teachers (Xie et al., 2023), and that teachers who are not familiar with digital resources may experience difficulty in using them appropriately (Drijvers et al., 2013). Teachers therefore may need training on technological pedagogical content knowledge (TPACK) (Spiteri & Chang Rundgren, 2020). In the DP4SET framework, we propose the use of teaching practices powered by quality digital resources. Evidence-based pedagogical practices that allow the utilization of quality digital resources (e.g. animations, videos, and reading materials) can be leveraged in a digital environment for improving curriculum design and student assessment (Mishall et al., 2022). For example, a course design that was supported by quality digital resources has been shown to enhance students' learning experiences in a virtual environment (Johnson et al., 2023). In a digital environment, technology grants teachers access to tools or resources (such as modules and tests) that enable them to assess students' performance and modify the curriculum when necessary (Alenezi, 2023).

Learning environments with applicable digital technology

To optimize learning, the digital learning environment should be embedded with relevant technologies (Crompton & Sykora, 2021). Technologies need to be appropriate to a specific discipline, subject, or training programme and integrated into the learning environment based on their applicability. The DP4SET framework proposes a new learning environment supported by technology that aims to promote seamless learning (i.e. learning can take place anywhere and at any time).

The synergy between human teachers and trustworthy AI

Education should be a fertile ground for human-AI synergy to promote effective learning among students (Holstein & Aleven, 2022). Past evidence has underscored that the partnership between humans and AI tends to be more effective than humans or AI alone (Holstein & Aleven, 2022; Kim, 2023). Humans and AI can complement each other's capabilities to help compensate for each other's weaknesses (Holstein et al., 2023). As an example of teacher-AI synergy, AI can help personalize learning, track student progress, and guide teachers in making informed instructional decisions (Kim, 2023). An intelligent human-machine synergy during collaborative teaching combines human and machine intelligence in diverse educational settings for an enhanced learning outcome (Huang et al., 2023). AI technologies can be used to complement the work of human teachers as a way of team or collaborative teaching (Huang et al.,2023). The shared roles between humans and AI should be apparent for meaningful partnership and instruction. Notwithstanding, achieving human-AI synergy is far from guaranteed (Holstein et al., 2023). There are instances where the use of AI to complement the work of human teachers yielded negative results (Holstein & Aleven, 2022; Poursabzi-Sangdeh et al., 2021). The conditions for AI to empower humans demand greater trust and a sustainable synergy between human and machine intelligence (Mercier-Laurent, 2023). Hence, we propose a 'trustworthy' (Vincent-Lancrin & Vlies, 2020) AI to achieve educational goals in the interactions between humans and AI. AI is considered 'trustworthy' when it is able to execute tasks as instructed, and when humans can be trusted to use it fairly and appropriately (Vincent-Lancrin & Vlies, 2020).

Policy insights

Within the context of the digital transformation of education, one of the objectives of the UNESCO Global Alliance on the Science of Learning for Education is dedicated to exploring the principles and practices of digital learning. It focuses on how to enhance learning outcomes through the design and implementation of innovative models, effective learning environments and instructional strategies based on digital technologies. Below are some policy insights for facilitating SCL using digital technologies.

Enhance the digital literacy of both teachers and students to promote active and deep learning. Active learning emphasizes the importance of learners actively participating in hands-on practice, exploration, and inquiry, which helps refine their cognitive structures and develop critical problem-solving skills. Fostering deep learning of students requires teachers to have a thorough understanding of the teaching content, enabling them to structure lessons effectively and design meaningful, engaging learning activities. To support this, comprehensive training programmes in digital literacy should be provided for both teachers and students. These programmes should focus on raising awareness of the potential of emerging technologies and fostering proactive learning and application among both educators and learners. Through these training programmes, teachers should be equipped to fully integrate digital technologies and resources in lesson planning, selecting appropriate instructional strategies, and effectively incorporating digital tools to enhance classroom teaching. The programmes should also emphasize the importance of teachers' ability to assess their instructional effectiveness and make real-time adjustments to lesson plans based on data-driven insights. Meanwhile, students should be empowered to apply digital tools for collaborative and self-directed learning. By utilizing digital tools for communication, collaboration, and knowledge-sharing with peers, students can construct deeper conceptual knowledge. Furthermore, they should be trained to use digital tools to plan, monitor, reflect on, and evaluate their learning processes, leveraging technology to promote independent learning and personal growth.

Promote the development of ethical and effective human-machine collaborative teaching-learning processes to support student-centred learning. Adapting to human-machine collaborative teaching is essential in the modern educational landscape where technology and AI increasingly complement traditional teaching methods. Educators should be supported to integrate AI-powered tools and platforms into their instruction, enabling a synergy between human insight and machine efficiency. This collaboration enhances personalized learning, provides real-time feedback, and allows for data-driven instructional adjustments. Concurrently, students should be encouraged to engage with these technologies actively, developing digital literacy and adaptability skills that are crucial for their future. Policy-makers should provide the necessary resources, training, and infrastructure to facilitate this transition, ensuring that both teachers and students can effectively navigate and benefit from a human-machine collaborative educational environment. This could include, for example, guiding students to work with AI assistants to set up learning goals, help with the selection of learning methods and strategies, monitor and control cognitive activities, adjust feedback, and manage behavioural motivation, thereby promoting effective learning. Concurrently, clear technical standards must also be established to ensure the ethical use of technology in education.

Facilitate global collaboration among diverse stakeholders to bridge gaps and enhance impact. International partnerships and cooperation are critical for knowledge exchange on effective digital education models, policies, tools and practices. Cross-sector cooperation among researchers, policy-makers, practitioners, and the private sector can be conducted through global forums and joint activities to address challenges such as the digital divide, data privacy, and the ethical use of educational technology. International cooperation can also facilitate the development of shared curricula and certification systems that recognize digital competencies and qualifications across borders to facilitate student learning.

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