Trends and Issues of Promoting Digital Learning in High-Digital-Competitiveness Countries: Country Reports and International Comparison

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PREFACE

With the rise of digital technologies, digital learning (DL) has created new opportunities and challenges for traditional education. This book aims to: (1) strengthen the mutual understanding and connection between Taiwan and other countries with high digital competitiveness in promoting DL in primary and secondary schools, so as to facilitate the development of each country's DL promotion projects; and (2) provide opportunities for countries with high digital competitiveness to share their experience of promoting DL, so as to facilitate international reference and common prosperity.

In this book, DL refers to the learning that is facilitated by digital technologies, and gives learners some control over time, place, path, and/or pace in an effective way, combining different elements such as blended or virtual learning. DL requires a combination of digital technology, digital content, and instruction. High-digital-competitiveness countries refer to the top 21 (or the first one third) countries listed in the IMD World Digital Competitiveness Ranking 2022, which placed Taiwan 11th out of 63 major countries and economies in the world.

The two editors-in-chief of this book developed manuscript guidelines, including comparison components, for each country report. They then invited 11 countries among the top 21 mentioned above to share their experience of promoting DL. After all country reports were received, reviewed, and necessary revisions were made, the two editors-in-chief and a doctoral student made a cross-country comparison. As a result, this book contains 12 chapters, including 11 country-specific reports and one chapter of cross-country comparison.

I am grateful to all the experts involved in the publication of this book. I hope that this book will improve DL, benefit students, and promote international collaboration.

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Trends and Issues of Digital Learning in Australia

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Abstract

This chapter examines the state of digital learning in Australian schools. Digitalization has become integrated throughout schools, playing an essential role in teaching, learning, administration and communication. Despite infrastructure constraints, many Australian teachers actively employ digital technologies to enrich learning experiences to prepare students for a digitally interconnected world. The Australian education system's approach to digital learning diverges from its OECD counterparts in several ways: A national curriculum mandates technology and digital literacy education for all students, ensuring consistent exposure from Foundation to Year 8 or 10. A strong emphasis is placed on online safety and digital citizenship education to protect students from online harm and foster responsible technology usage. Furthermore, coding and problem-solving skills are explicitly integrated into the curriculum, acknowledging their significance in a technology-driven world. Current trends in digital learning in Australian schools include widespread technology integration; the growing prominence of online education; the popularity of *integrated* STEM (Science, Technology, Engineering & Mathematics) education, experimentation with artificial intelligence (AI) tools and the use of educational computer games in classrooms. While these developments offer valuable advantages to students' learning outcomes, increasing concerns are being raised by parents and community groups about students' excessive dependence on technology. Digital learning requires high-quality programs and support, with AI tools holding promise in addressing this. However, challenges loom over the future of quality digital learning in Australian schools. Anticipated acute teacher shortages pose a risk to educational standards. The digital divide, which limits access to digital learning, remains a pervasive issue, impacting disadvantaged students, with an over-representation of First Nations' students. While digitalization has made substantial progress, significant challenges must be confronted to ensure the realization of the 'Education Goals for Young Australians' (Education Council, 2019) which promotes excellence and equity in education so that Australia produces confident, informed and successful lifelong learners.

Keywords: Australia, technology integration, curriculum, online learning

Introduction

The stated Education Goals for Young Australians (Education Council, 2019), as declared by all Australian Education Ministers are:

Goal 1: The Australian education system promotes excellence and equity.
Goal 2: All young Australians become confident and creative individuals, successful lifelong learners, and active and informed members of the community.' (Education Council, 2019, p. 4)

The principals contained in these Goals underpin the direction of policy and curriculum in Australian education. When it comes to digital learning, it is the issue of 'equity' in Goal 1 that has been the most challenging to achieve. This difficulty will be addressed more fully in the Issues section of this chapter.

The Structure of the Australian Schooling System

The Australian education system is structured as Figure 1. The components of the Australian schooling system are described below:

Figure 1 Australian Education System

Early childhood education

Formal early childhood education serves various purposes, including childcare and supervision, preparing children for school, and ensuring their readiness for future learning opportunities. Early childhood education programs are offered through community programs, pre-schools, and various child-care settings, such as long day care and family day care. While the three most populous states have just announced one year of free pre-school education for all (and the remainder are expected to follow soon), the cost of early childhood education has been historically subject to a means test based on parents' incomes, making it relatively expensive for some families (often amounting to as much as AUD $160 per day per child). Despite these costs, Australia witnessed a significant increase in participation rates for 4-year-olds, rising from 53% in 2005 to 87% in 2022 (AGDE, 2022a), representing the fourth highest increase in the OECD (OECD, 2016). It is anticipated due to the change in government policy, that this rate will rapidly rise from 2024.

Primary schools

Children are required to begin school by the age of 6, with most children commencing between the ages of 4½ - 5½ years. Primary school typically spans from Foundation to Year 6 and focuses on building essential literacy, numeracy, and social skills while imparting foundational knowledge about the world. As students progress from primary to secondary school, subjects become increasingly specialized, with specialist teachers being employed in secondary schools.

Secondary schools

Secondary schools cater to students aged between 12-18 years in Years 7 to 12. Upon completing Junior High School (Years 7-10), some students transition to Specialised Senior High Schools or Colleges to complete Years 11 and 12. In regions where there are small populations, students aged 5-15 years often attend Central Schools (Foundation-Year 10).

Students who complete their secondary education at Year 12 receive a Senior Secondary Certificate of Education. Subsequently, they may pursue vocational or higher education courses and/or enter the workforce. In 2022, the secondary retention rate in Australia (the percentage of students who started Year 7/8 and completed Year 12) was 80.5% for males and 87.8% for females (ABS, 2022). Since 2010, all States and Territories mandate that students complete Year 10 and engage full-time in education, training, or employment until at least 17 years of age.

Features of the Australian schooling system

The Australian academic year typically commences in late January or early February, running through to mid-December, with most schools operating on a four-term school year. Funding for childcare, pre-schools and all schools (Government, Catholic, and Independent schools - the latter includes other faith-based institutions) is jointly managed by the Australian and State Governments, although the State Governments bear the bulk of the responsibility for funding all State schools. State schools charge nominal tuition fees; however, Independent school tuition fees can be as much as AUD $45,000 per annum for the final secondary school year.

The Australian education system features a high level of privatization, both in the school and higher education sectors, when compared to other OECD countries (OECD, 2016). In 2022, 30.4% of school student enrolments were in private schools (Independent and religious), while most higher education enrolments (93%) occurred in public universities (ABS, 2022).

Government control extends to student assessment, course accreditation for both government and non-government schools, and early childhood learning centres. It should be mentioned that the Australian education system is noted for its robust regulatory framework and transparent accountability mechanisms. Since 2012, Australia has implemented a National Curriculum, ensuring common curriculum frameworks and learning outcomes across all schools, from Foundation to Year 12. This curriculum was developed by ACARA (Australian Curriculum, Assessment and Reporting Authority), which also administers the annual assessment Program – Literacy and Numeracy (NA-

PLAN) for students in Years 3, 5, 7, and 9 (ACARA, 2022a).

Digital Transformation (DX) and Current Stage in Australian Schools

At all levels of the Australian Education system, Stage 2: Digitalization has been achieved. Technologies play an integral role in the administration, communication, and financial functions of each educational institution, as well as of the systems in which they are a part. Government and system regulations require all school reporting and record keeping for accreditation and certification purposes to be undertaken and submitted digitally.

Furthermore, Stage 3: Digital transformation is commonly realized at a systemic level. Governing bodies at each level of education (Early Childhood, Primary, and Secondary education), and across sectors (Government, Catholic, and Independent), routinely employ digital technologies to collect, analyse, and report on data received from individual institutions, aiding in decision-making. This practice allows schools, systems, and sectors to monitor and assess the effectiveness of their educational approaches and identify institutions requiring additional support (AERO, 2023).

Collected data are frequently utilized by teachers to assess student learning and plan future teaching programs. Student data collected from national testing (individual and aggregated), such as NAPLAN, are made accessible to schools and educators, who employ sophisticated analytical tools to identify trends, and actively work toward improving planning for future learning. According to the most recent Teaching and Learning International Survey (TALIS), Australian schools rank third among OECD countries in their consumption of information and communications technology (ICT) (OECD, 2019).

The Status of Digital Learning in Australian Schools

Digital learning within the Australian Education system is influenced by several key documents and frameworks. These documents help shape how digital learning is delivered to different age groups in Australian classrooms.

Contexts of Digital Learning in Australian Schools

Early childhood education

For those in Early Childhood Education, the Early Years Learning Framework (EYLF) serves as a guiding document. It outlines a shared vision for young children's learning, the principles and practices that underpin teaching and learning, along with five learning outcomes – two of which directly reference digital learning:

'Outcome 2: Children are connected with and contribute to their world.' This acknowledges that children increasingly connect with others through digital contexts, involving sharing and communicating information via digital technologies and the internet.

'Outcome 4: Children are confident and involved learners.' This outcome encourages children to choose and use appropriate tools, technologies, and media to enhance their learning (AGDE, 2022b).

Primary and secondary schools

In primary and secondary schools, the Australian Curriculum is the most influential document when determining what occurs in Australian classrooms. All schools are required to demonstrate that they are teaching the content and skills outlined in this curriculum. The national curriculum aims to provide a high standard of curriculum content for every Australian student, regardless of their individual circumstances. One of the biggest challenges to this aim is geographical location. Australia is a large, and often sparsely populated country, and the challenges this brings will be addressed later in the chapter.

The Australian Technologies Learning Area Curriculum recognizes technology education as a vital component of students' learning, and Digital Literacy Capability outlines how digital literacy is considered an essential skill and is to be taught across all learning areas (ACARA, 2022a). The curriculum emphasizes the need for students to be active participants in a technologically rich environment. The curriculum's goal is to equip students with the skills to make ethical and moral choices about emerging technologies and to modify technologies to suit their needs. The Technology Learning Area encompasses a range of knowledge and skills designed to help students become confident producers, not just users, of technology. Students are expected to develop their skills while exploring various technologies through projects and activities that include experiences with coding and robotics (Cameron, 2020).

Every three years, primary and secondary students' technology skill levels are assessed through national standardized testing. Unlike NAPLAN tests, which are administered to all students in Years 3, 5, 7, and 9, the Technologies test (NAP-ICTL) evaluates a random sample of Year 6 and Year 10 students from schools across Australia. The test measures students' ability to use digital technologies appropriately and safely, develop new understandings, apply computational and design thinking, communicate & collaborate, and engage with emerging technologies. De-identified results are made publicly available (ACARA, 2022b).

Digital learning policies, projects/programs, strategies and R&D

While Australia's mandated overarching policy documents are outlined above, Early Years Learning Framework (AGDE, 2022b) and the Australian Curriculum (ACARA, 2022c), the Australian Government have introduced a range of other initiatives to support digital technologies in schools:

- The *Digital Education Revolution Project* (DER) (DEEW, 2011) was an initiative to provide every Year 11 & 12 high school student with access to computers and digital resources. It was later integrated into broader school support programs.

- The *National Innovation and Science Agenda* (NISA), (AGDE, 2017) aimed to improve digital literacy skills by funding a wide range of projects:
    - Digital Technologies massive open online courses (CSER MOOCs) to provide free professional learning for teachers and a National Lending Library to provide new technologies to schools.
    - The Digital Technologies in Focus (DTiF) project to provide support for 160 disadvantaged schools to assist them in implementing the Australian Curriculum: Digital Technologies.
    - Australian Digital Technologies Challenges series of free online teaching and learning activities for students in Years 3 to 8.
    - digIT series of summer schools targeting Year 9 and 10 students from under-represented groups to engage them in digital technologies and related careers.
    - Digital Literacy School Grants that provided funding to 114 projects supporting innovative ways of implementing the Digital Technologies curriculum in schools.

- The *National STEM School Education Strategy 2016–2026*. (AGDE, 2016) focuses on developing foundational skills in mathematical, scientific and digital literacy, and promoting problem solving, critical analysis and creative thinking skills. The strategy aims to coordinate current activities and improve STEM education.
- Education Services Australia (ESA, 2023) has ongoing funding to manage the *Digital Technologies Hub* (www.digitaltechnologieshub.edu.au), an online repository of teaching resources for F–10 Digital Technologies cur-

riculum resources.

- The *Office of the eSafety Commissioner* (2023) has ongoing funding to provide resources to promote safe online environments for children and young people. This includes resources for educators and schools to help them integrate digital technologies in a safe and responsible manner.

Australia's Technologies Curriculum was influenced by a range of international research, namely Bloom's Taxonomy (Krathwohl, 2002), TPACK (Mishra & Koehler, 2006) and the SAMR model (Puentedura, 2013). However, the research centres listed below regularly collaborate with government and non-government organizations, schools, and communities to conduct research, trials, and implementations in Australia. They play a pivotal role in shaping the digital education landscape.

- *Australian Council for Educational Research (ACER)*

Research Areas: Assessment and reporting, digital literacy, teacher professional development, and curriculum design.

- *Learning Sciences Institute Australia (LSIA) - Australian Catholic University*

Research Areas: Learning analytics, digital technology's role in pedagogy, and technology-driven student engagement.

- *Science of Learning Research Centre (SLRC)*

Research Areas: Role of technology in enhancing cognitive processes, digital tools for classroom engagement, and learning analytics.

- *Innovative Learning Environments and Teacher Change (ILETC)*

Research Areas: Spatial reasoning in digital environments, technology-driven pedagogical change, and design of digital learning spaces.

- *Centre for School Leadership, Learning and Development (CSLLD) - University of Tasmania*

Research Areas: Digital pedagogies, technology-driven curriculum development, and leadership in the digital age.

- *Centre for Children and Young People (CCYP) - Southern Cross University*

Research Areas: Online safety in schools, digital citizenship, and the role of technology in holistic child development.

Digital learning implementation in Australian schools

In Australian schools, the integration of digital learning is influenced by several factors, including government-funded initiatives (as listed above), teacher attitudes, and infrastructure challenges. With significant government funding supporting digital learning, a substantial 78% of Australian teachers frequently allow students to use technologies for projects or classwork (Gonski, 2020). This percentage is notably higher compared to the OECD average of 53% (OECD, 2019).

A recent study (Gonski, 2020) revealed that teachers who integrated digital learning enjoyed various advantages in their classrooms, including employing student-directed learning, access to global information, and the ability to share and receive knowledge in real time. The study reported that teachers recognized many benefits of digital learning for their students. For instance, two-thirds of teachers agreed that technology enhances inquiry-based learning, and 43% thought that digital learning improves classroom teaching and learning. Moreover, digital technologies were seen as particularly beneficial for students with special educational needs, with 60% of teachers believing it positively contributes to their learning. The OECD (2019) reported that Australian students spend at least 39 minutes per day online at school, and they perform better in digital reading compared to print reading.

Digital learning is extensively implemented in Australian K-12 schools, driven by government support and recognized benefits. Despite challenges in digital infrastructure and the impact of COVID-19, schools and teachers are actively using technology to enhance learning outcomes and prepare students for a digitally connected world.

Digital literacy implementation in early childhood education centres

The Early Years Learning Framework (EYLF) (AGDE, 2022b) outlines the principles, practices, and learning outcomes essential for supporting and enhancing young children's learning. While the EYLF does not prescribe specific technologies or digital tools, it does emphasize a holistic approach to learning, recognizing the potential of technology to support various areas of children's development. While digital learning is embraced, there is also a strong emphasis on ensuring children continue to have plenty of natural, hands-on, play-based learning experiences. Outdoor play, physical activities, and real-world interactions remain fundamental in early childhood settings.

To support digital learning, early childhood centres often invest in technologies such as iPads, tablets, interactive whiteboards, and high-speed internet. Interactive digital storybooks, educational apps and games that enhance cognitive skills and digital drawing and art programs are the tools which children of this age most regularly engage with.

Digital platforms are often used to enhance communication between educators and families. Apps and platforms allow parents to receive updates about their child's day, view photos, and communicate directly with educators. With the introduction of digital learning, there are valid concerns regarding screen time, data privacy, and the commercialization of education to the point that some centres elect not to have any digital devices for children's use.

Digital literacy implementation in primary schools

Many Australian primary schools take a multifaceted approach that integrates technology into various Learning Areas of the curriculum, while also ensuring that students remain safe, informed, and engaged. Most frequently these schools provide students with access to school-owned digital devices while in class, such as iPads, tablets, laptops, or desktop computers. Some primary schools have 1:1 device programs where each student has access to their personal device for learning, but this is not common and usually only occurs in the upper Primary Years (Years 5 & 6).

The Australian Curriculum outlines the required knowledge, skills, and dispositions for all primary students. Consequently, coding is increasingly being integrated into the curriculum. Resources such as Scratch Jnr, Bee-Bots, Cubetto and/or Dot & Dash can be found in the lower Primary Years' classrooms. Upper Primary years students will be undertaking more explicit visual (block) coding activities using technologies such as Scratch, Code.org, Minecraft Education Edition, LEGO Mindstorms and/or LEGO Education Spike.

Learning Management Systems (LMS) like Google Classroom, SeeSaw, Canvas, Microsoft Teams, Moodle or Edmodo are commonly used in primary schools. These platforms enable teachers to distribute materials, assign tasks, provide feedback, and communicate with students and parents. Interactive whiteboards or digital projectors, and educational software applications are also evident in most primary schools.

Digital literacy implementation in secondary schools

Technology education becomes more specialized as students transition from primary to secondary school, reflecting the diverse subjects and the depth of content explored. The Australian Curriculum has a Digital Technologies subject for Years 7 & 8, in which students learn key computing concepts, information systems and digital systems. Students engage in more advanced general purpose (text-based) coding programs, for example, Python or Ruby. In Years 9-12, students can elect to delve deeper into specialized courses related to information technology and explore programming languages such as Java or C++.

Bring Your Own Device (BYOD) programs and school-based devices are common in secondary schools. Students use these devices for research, assignments, and various learning activities. Depending on the courses the students elect to take, they may use specialized software. For example, Design & Technology students might use CAD software, while music students might use digital audio workstations. Increasingly schools are integrating virtual reality (VR) and augmented reality (AR) tools to provide immersive learning experiences, especially in subjects like science, history, or geography.

Learning Management Systems (LMS) become even more integral in secondary schools. They facilitate the distribution of resources, assignment submissions, feedback, and communication between teachers, students, and parents. Staff and students can often access online databases, e-journals, and digital libraries through their LMS. Senior students may have opportunities to undertake online courses, sometimes from universities, to supplement their learning or to get a head start on tertiary education.

The impact of COVID-19 on digital learning in Australian schools

It is important to note that the impact of COVID-19 on digital learning in Australian schools was not uniform. It varied depending on factors like the geographical location of the school, the resources available, and the readiness of teachers and students to embrace digital learning. Some Australians experienced prolonged lockdowns due to COVID-19 where everyone had to remain in their homes (Melbourne had six lockdowns totalling 262 days during 2020-2021). The rapid shift to remote learning in 2020 brought equity and access issues to the forefront. The digital divide became evident when students were suddenly required to learn from home. Some students faced challenges due to a lack of devices or reliable internet access. Many schools were able to provide devices to those students without access, while state governments subsidized home internet and device costs for the most disadvantaged students. The Australian government and education sectors worked to improve internet connectivity in remote and underserved areas to ensure that all students had access to online learning.

Many students had to share devices among family members, and some relied on printed worksheets posted out by schools. Even with ready access to devices and home internet, keeping engaged and motivated in a digital learning environment was challenging for even the best students. Many students struggled with self-discipline and staying focused without the structure of a traditional classroom. It was expected that parents would become more involved in their children's education, with many required to take on the role of at-home teachers which required them to navigate digital learning while often trying to maintain their own jobs. The success of this very much depended on the parents' education levels and their comfort with digital learning.

Much of the disconnect experienced during this period was due to how quickly schools had to pivot to solely relying on remote digital learning during lockdowns. Many schools started using learning management systems for the first time to deliver online lessons, share resources, and track student progress. Popular platforms like Google Classroom, SeeSaw, Canvas, Microsoft Teams, Moodle or Edmodo became essential tools for teachers, and have commonly remained in use.

All teachers were required to adapt to the new digital learning environment, leading to a desperate need for increased professional development in the use of educational technology. This included online professional development and sharing best practice. The pandemic forced schools to rely more heavily on digital textbooks, e-books, and online educational content. The increased screen time and isolation due to remote learning raised concerns about the mental health and well-being of students. Schools have had to address these issues and provide support.

The aftermath of education during this period is still being felt by many students and teachers. Most schools have continued to use simple hybrid or blended learning models as a long-term digital learning strategy, combining in-person and online scaffolded instruction, as the benefits of enhanced flexibility and the accommodation of different learning styles were made evident during the pandemic.

Digital Learning Infrastructure

Digital learning infrastructure in Australian schools

In Australia, there is at least one computer per student, with 95% connectivity (OECD 2019). The increased reliance on IT infrastructure in the Australian education system has put pressure on aging IT systems, and has strained limited IT budgets. Poor infrastructure can affect Wi-Fi connections and limit internet access. Slow internet due to network bandwidth limitations is a significant challenge, especially in rural schools and older buildings. Government initiatives are being undertaken to enhance internet access, particularly in rural areas (NSW Government, 2023a). However, in some schools the reliability of Wi-Fi remains an issue. In those schools, teachers often need to plan two versions of lessons, one for when technology works and one for when it does not (Krueger, 2022).

Technology infrastructure varies by school and location. However, there has been a push for improved connectivity and bandwidth in K-12 schools. The government, through initiatives like the Schools Broadband Initiative (ADDMC, 2022), aims to ensure that schools have access to high-speed internet. Many schools have also invested in Wi-Fi networks and upgraded their IT infrastructure. Since 2021, the COVID-19 pandemic has accelerated the adoption of digital learning and the government has committed to enhancing the digital infrastructure in schools to support remote and blended learning.

Realising digital learning in Australian schools is a complex undertaking which relies heavily on leadership and budgetary considerations. It is not solely a federal government responsibility; state and territory governments also exert influence by implementing and financing digital learning programs in accordance with their specific needs and priorities. At the school level, leadership and management are entrusted with the crucial task of allocating budgets for technology infrastructure, teacher training, and digital learning resources. This intricate relationship between federal, state, and school-level leadership sets the stage for inconsistent digital learning in Australian schools.

ACARA provides overarching guidelines but schools and educators enjoy a degree of autonomy in shaping the design and delivery of digital content. This flexibility at school level does, however, allow for adaptation to local needs and pedagogical philosophies. Commonly, learning management systems (LMS) and online platforms are leveraged to deliver content, assignments, and assessments. These tools offer an interactive platform that allows student engagement and collaboration, helping students explore their subject resources. Course design and delivery have experienced significant evolution, as a result of the COVID years.

In the pursuit of student success, there is an increasing focus on providing equitable access to digital resources and support. Personalised learning and adaptive technologies have emerged as strategies to cater to individual student needs, allowing for differentiated instruction that aligns with varying learning paces and styles. Data-driven interventions play a critical role in this process, helping teachers identify and support struggling students, thereby promoting student success in digital learning environments. Evaluation and analytics are integral components of this process. Teachers and schools utilize data analytics to monitor student progress and gauge the effectiveness of digital learning tools. Concurrently, government bodies and educational institutions often engage in research and evaluation studies to ascertain the impact of digital learning on educational outcomes. These evaluations provide valuable insights for refining and enhancing digital learning strategies.

Budget constraints have led some schools to adopt Bring Your Own Device (BYOD) policies, wherein students bring their own devices for classroom use. This strategy helps mitigate the financial burden on schools while still providing students with access to essential technology. A recent Australian Computer Society (ACS) report (Zagami, 2022) found that 70% of high schools and 32% of primary schools used bring-your-own-device (BYOD) programs in 2022. Furthermore, Service Level Agreements (SLAs) have been established between schools and various service providers. These agreements often include provisions for high availability to ensure that digital services remain accessible and dependable, guaranteeing a smooth learning experience for students.

Teacher and staff professional development stands as a critical component of this digital transformation. Many schools offer training programs to ensure teachers are proficient in using technology in the classroom. Additionally, organizations like the Australian Institute for Teaching and School Leadership (AITSL) have developed guidelines for incorporating digital skills into teaching, ensuring that educators are equipped to harness the full potential of digital tools for the benefit of their students.

While student success in digital learning is stated as a primary goal of the Australian education system, schools are increasingly focused on providing equitable access to digital resources and support. Personalized learning and adaptive technologies are used to cater to individual student needs. Data-driven interventions help identify and support struggling students, however finding the funds to provide the recommended support is sometimes challenging.

Key statistics and practical examples

Below is an outline of digital learning infrastructure in Australian schools. This list provides a very broad overview of some of the key elements of the digital learning infrastructure in Australian schools (ACARA, 2022a; DESE, 2021):

- 97% of Australian schools have access to the National Broadband Network (NBN).
- 95% of Australian students have access to a device at school.
- 86% of Australian teachers feel confident using digital technologies in the classroom.
- 82% of Australian schools have a digital learning strategy in place.
- 75% of Australian schools have a dedicated digital learning leader.

Examples of the most common digital learning infrastructure found in Australian classrooms are:

- Interactive whiteboards: Interactive whiteboards are a common feature in Australian primary classrooms, providing teachers with a large, interactive surface to work on.
- Learning management systems (LMSs): LMSs such as Google Classroom, SeeSaw, Canvas, Microsoft Teams, Moodle or Edmodo are used by many Australian schools to provide students with access to learning resources and assignments.
- Digital libraries: Digital libraries such as OverDrive, ClickView and Wheelers ePlatform provide students with access to a wide range of ebooks and audiobooks.
- Coding programs: Many Australian schools now offer coding programs to students, teaching them the skills they need to create their own digital content, eg. Grok Academy.
- Robotics programs: Robotics programs are also becoming increasingly popular in Australian schools, helping students to develop their problem-solving and critical thinking skills.
- Virtual Reality (VR) and Augmented Reality (AR): VR and AR technologies are being used in some Australian schools to create immersive and interactive learning experiences.
- Maker spaces: Maker spaces are dedicated spaces in schools where students can use a variety of tools and materials, including 3D printers and

laser cutters, to create their own projects.

Below are some specific examples of how digital learning infrastructure is being used in Australian schools (ACARA, 2022a; ESA, 2020):

- Callaghan College (New South Wales) students are using 3D printers to design and create prototypes of new products.
- Bendigo Senior Secondary College (Victoria) students are using coding to develop their own video games and apps.
- At Northmead Creative and Performing Arts High School (New South Wales), students are using digital storytelling tools to create and share their own stories.
- At St Patrick's College (Queensland), students are using virtual reality headsets to explore historical sites and scientific concepts.
- At Melbourne Girls Grammar (Victoria), students are using a maker space to build robots, design and print 3D objects, and create animations.

These are just several typical examples demonstrating how digital learning infrastructure is being used to support learning in Australian schools. As technology continues to evolve, it is expected schools will adopt even more innovative ways to use digital tools and resources to enhance student learning.

Features of Digital Learning

One Technology curriculum for all Australian students

It has previously been mentioned in this chapter that Australia has a national curriculum that is prescribed for all schools to deliver. That is, all students study Technology and Digital Literacy from Foundation-Year 8 (in some states it is through to Year 10). This is a key feature of the Australian education system, and it has been designed to ensure every Australian child has cohesive and sustained experiences with digital learning.

Technologies is a Learning Area of rapid change and in recognition of this, the advisers and writers of the Australian Technologies Curriculum were careful to ensure the new curriculum was as future-proof as possible. Their approach demonstrated a desire to prepare our students to make informed choices about their future. The over-arching Core Concept of the Technologies Curriculum is 'creating solutions for preferred futures' (ACARA, 2022a). This provides a methodology for identifying and moving towards socially responsible and sustainable patterns of living. Students are required to identify the possible benefits and risks of creating solutions and recognise that views about preferred futures are contested (Cameron, 2020a).

There are two distinct subjects within the Technologies Learning Area: Design & Technologies and Digital Technologies. Design and Technologies has a strong focus on design thinking, the application of the design process and producing (making) solutions to design products, services and environments. In the Digital Technologies subject, the focus is on the use of digital systems, information and computational thinking to create solutions for identified needs and opportunities (Cameron, 2020).

The Digital Technologies subject content focusses on a comprehensive understanding of the key ideas of Computer Science that have remained constant for decades. Along with the Core Concepts of the curriculum, these establish a way of thinking about problems, opportunities and information systems which provide a framework for knowledge and practice that automation cannot currently duplicate.

The critical role of the general capabilities

In addition to the content in the various Learning Areas, the Australian Curriculum includes General Capabilities which encompass the knowledge, skills, behaviours and dispositions to equip students to live and work successfully in the future (ACARA, 2022b). These Capabilities are taught through the

Learning Area content and can readily be incorporated into any subject. They include the skills that have been highlighted as being critical to preparing our students for the workforce. Future workers will need to be literate, numerate, ethical and digitally literate (Hajkowicz et al., 2016). The Digital Literacy, Ethical Understanding, Critical & Creative Thinking, Literacy and Numeracy General Capabilities align directly with these characteristics.

There is much work to be done around the ethical, legal and governance frameworks to ensure that robotics and AI technology are used for good, and that transparent processes are in place to ensure accountability at all levels (Southgate et al., 2019). The General Capabilities, most especially the Digital Literacy, Critical & Creative Thinking and Ethical Understanding Capabilities, provide topical and authentic source material with which Australian students can discuss/debate how the issues surrounding emerging technologies might relate to their own lives and future careers.

Online safety and digital citizenship education

The Digital Literacy Capability (ACARA, 2022c) was revised to place more significant emphasis on teaching students about online safety, that is, how to protect themselves from harm online, including understanding the risks of online interaction and developing strategies for staying safe (ACER, 2020), and digital citizenship (the ability to use technology responsibly and ethically, including understanding one's rights and responsibilities as a digital citizen and developing critical thinking skills to evaluate online information and make informed decisions (ACER, 2020).

This change came about as a growing body of research emerged that called for online safety and digital citizenship education in schools. A study by the eSafety Commissioner (2020) found that students who participated in online safety education programs were more likely to be aware of online safety risks and to have strategies for staying safe online. The Australian Council for Educational Research (ACER, 2020) also found that students who participated in digital citizenship education programs were more likely to use technology responsibly and ethically.

The Digital Literacy Capability includes an element, ‘Practicing Digital Safety and Wellbeing’ where the focus is on educating students about managing their online safety, their digital privacy and identity and their digital wellbeing (see Figure 2).

Figure 2 The Elements of Digital Literacy Capability

Source: ACARA V9.0: Understand this general capability: Digital Literacy

As students increasingly used digital devices and online platforms both in their school and at home, there were concerns about their online safety knowledge and practices. It was clear that schools needed to educate students about online safety, including protecting personal information and avoiding cyber threats. Additionally, the necessity to teach students responsible digital citizenship was also considered essential, but, even with this change to the curriculum, it is challenging to ensure that students practice these principles consistently both in and out of school.

Compulsory coding and 'thinkings' for all students Year 3 and above

The Australian Technologies Learning Area requires students to learn a wide range of fundamental computing concepts while developing their thinking skills (Computational, Systems and Design) and problem-solving capability. Coding (also known as computer programming) is introduced to Australian students from Year 3, but it is used primarily as a tool, not as the main outcome of the subject (Zagami, 2022).

Students learn and use several programming languages to varying degrees during their time at school. None of these will be learnt comprehensively to the detailed level of specific programming language courses in industry and tertiary studies, but collectively students will explore all the fundamentals common to scripting, procedural and functional programming languages, and query languages, and have an introduction to object-oriented programming in the Year 9 and 10 elective. Senior secondary computer education courses are generally more comprehensive in their coverage of computing languages (Zagami, 2022).

The Technology curriculum requires the explicit teaching of several different ways of thinking, ideally to be incorporated in practical ways as students complete Technology projects (Education Services Australia, 2020):

Computational thinking - a process where a problem is analysed and solved so that a human, machine or computer can effectively implement the solution. It involves students using strategies to organise data logically, break down problems into parts, interpret patterns and design and implement algorithms to solve problems.

Systems thinking - an understanding of how related objects or components interact to influence how a system functions. It is important they understand the complexity of systems and the interdependence of components for the creation of solutions to technical, economic and social challenges.

Design thinking - involves a process where a need or opportunity is identified, and a design solution is developed. The consideration of economic, environmental and social impacts that result from designed solutions are core to design thinking. Design thinking methods can be used when trying to provide a structure to assist students in understanding a problem, generating ideas and refining a design based on evaluation and testing (Cameron, 2020).

This knowledge included in the Technology curriculum was designed to help students work in innovative and creative ways – essential skills for the entrepreneurial needs of a rapidly changing future.

Trends and Issues in Digital Learning

Trends in Digital Literacy in the Australian Schooling System

1. The integration of technology in all aspects of the education system

Technology has become an integral part of Australian schools for delivery of learning, communication, and administration. The integration of laptops, tablets and interactive whiteboards is commonplace in most classrooms. With the sudden introduction of online remote teaching due to COVID-19 lockdowns, schools were rapidly forced to incorporate digital learning and online platforms into their lesson delivery. Learning Management Systems (LMS) have become a staple, allowing teachers to organize content, assignments, and assessments online. During the COVID-19 pandemic, easy access to content in LMSs not only streamlined administrative tasks but also provided a central hub for students to access course materials and submit assignments. This allowed both teachers and students to access educational materials from home, ensuring anywhere, anytime learning is possible.

With a lack of government ongoing funding to fully support digital infrastructure in schools, many schools have adopted BYOD (bring your own device) programs. Students are required to provide their own laptops or tablets, to enable them to access classroom learning materials. This approach fosters more individualized learning, as students can progress at their own pace and explore subjects in depth.

The traditional chalkboard or whiteboard has been replaced in most classrooms. Interactive whiteboards are still commonplace in many primary schools but data projection from a teacher's laptop is now more typical. This allows digital displays of teacher presentations which can offer more dynamic teaching tools, allowing educators to create interactive lessons, use multimedia resources, and engage students with hands-on activities.

Technology has become deeply integrated into the Australian school classroom, offering numerous benefits, including access to information, enhanced collaboration, and engaging learning experiences. While technology's advantages are clear, Australian teachers are becoming increasingly aware of the dangers of an overreliance on technology (this issue is developed later in the chapter).

2. The growing importance of digital learning for both teachers and students

Digital learning and blended learning are becoming increasingly popular in Australian schools, as they offer both teachers and students more flexibility, convenience and choice. Digital learning is the delivery of instruction and assessment through digital technologies, while blended learning is a combination of digital (remote) and face-to-face instruction. Employing digital learning can also be more cost-effective for schools than traditional face-to-face instruction. However, it is important to ensure that digital learning programs are of high quality and that students have the necessary support to succeed.

Digital delivery can also help teachers to better differentiate their instruction. Teachers can use online learning platforms to create modified assignments and learning activities for students with different learning needs and abilities. Learning can be undertaken at the learner's own pace and in their own time, and learning resources can be accessed from anywhere with an internet connection. In a country the size of Australia, there are obvious advantages to this form of instruction over traditional face-to-face learning. Digital learning is now the go-to form of delivery for much teacher professional development.

There is a growing body of research that supports the use of digital learning in schools. For example, a study by the Australian Council for Educational Research (ACER) found that students who participated in online learning programs made significant gains in academic achievement (2022). Online platforms, which include LMSs now commonly used in schools, offer features such as discussion forums, shared documents, and multimedia integration, fostering a dynamic environment where students collaborate irrespective of geographical constraints.

Digital assessment and feedback technologies have recently begun to emerge in Australian schools. These tools have the potential to transform the way that learning is assessed and supported. However, it is important to ensure that teachers are adequately trained on how to use these tools effectively and that all students have access to the necessary digital devices and internet connectivity.

The impact of digital and blended learning for many students in Australian schools has been significant. Schools have been required to develop effective policies and practices for implementing digital and blended learning to safeguard student wellbeing and address student disadvantage, and for managing student data in online environments. Ensuring the quality and accuracy of online educational content is also of vital importance to the success of digital learning.

3. Utilization of artificial intelligence (AI) is gaining popularity in teaching and learning

Australian teachers and students are beginning to use generative AI tools in a variety of ways. With the recent declaration that AI tools are permitted to be used for teaching and learning activities by both teachers and students in all Australian schools from 2024 (Cassidy, 2023), their use in the classroom is predicted to rise exponentially. For this reason, the Education Minister has announced that a 'National AI in Schools Framework' will be introduced, and a Consultation document is currently available (NSW Government: Education, 2023b).

One of the most popular applications of these AI tools has been in content generation for teaching. Traditional methods required teachers to spend long hours preparing lessons and classroom activities. With the assistance of generative AI, teachers can create a wide array of content, from poems and stories to coding exercises, in a fraction of the time. This not only provides teachers with more time to focus on students but also ensures a diverse range of teaching materials, tailored to current trends and knowledge.

Professional development sessions for teachers on the effective use of AI tools have surged in popularity, indicative of the enthusiasm for AI tools within the education sector. Teachers are keen to harness the capabilities of generative AI, not only for content creation but also for personalizing the learning journey for each student. Traditional teaching materials are often generic, designed for the average student. Generative AI, however, offers a paradigm shift. By analysing a student's performance, preferences, strengths, and weaknesses, the AI tool can create customized quizzes, worksheets, and even assessment tasks. This level of personalization ensures that no student is left behind, and each receives an education tailored to their unique needs.

Students, too, are benefiting from the AI-driven approach. Immediate feedback provided by AI tools enables students to identify and rectify their mistakes. This immediate response not only accelerates the learning process but also builds students' confidence. Encouraging students to submit first drafts for AI review means that teachers receive a final polished version for evaluation, making the grading process more efficient and accurate. It also allows teachers to focus on providing qualitative feedback, which can significantly improve a student's learning experience.

4. The rise of integrated STEM education

One of the most notable shifts in Australian schools in recent years is the emphasis on integrated STEM (Science, Technology, Engineering and Mathematics) education. In this interdisciplinary approach, students typically undertake practical, hands-on projects, events or competitions where they can showcase their creations and solutions. STEM projects in Australian schools often focus on real-world problems. This can include designing sustainable housing solutions, creating water filtration systems, or programming robots to perform specific tasks; students are given hands-on opportunities to solve challenges. When students see the practical application and relevance of what they are learning, it assists their understanding.

By combining STEM subjects in this practical way, students see the inter-connectedness and relevance of these subjects. This problem-based learning approach fosters creativity, critical thinking, and collaboration - essential skills, not just for STEM fields but for any future profession and life in general. It is projected that many of the jobs of the future will require STEM skills. However, this is not just about producing scientists and engineers, it is to equip all students with a STEM literacy that will benefit them regardless of their career paths. The Australian government and educational bodies recognize this and have invested significantly in STEM education.

While the benefits of integrated STEM projects are many, they are not without challenges. For effective implementation, schools require adequate resources, trained teachers, and a curriculum that supports interdisciplinary learning. Moreover, striking a balance between academic rigor and hands-on exploration is essential to ensure students receive a comprehensive education. Inclusivity is also a crucial factor. Historically, certain groups have been underrepresented in STEM fields. Australian schools are increasingly recognizing the importance of ensuring that all students, regardless of gender, cultural background, or socio-economic status, have equal opportunities and encouragement to engage in STEM.

5. The increased use of computer games, gamification, and eSports

Computer games are being used increasingly in Australia. Games like 'Minecraft: Education Edition' have found a place in many primary schools, helping students understand complex concepts such as mathematics, ecology, and history in an interactive way. Through these games, students can construct virtual worlds, solve problems, and collaborate with peers.

Many schools have purchased educational games tailored to specific subjects to provide an adaptive learning environment; for example, in secondary schools, games designed to teach languages or science are common. These games adapt to a student's progress and understanding and offer targeted challenges and feedback. This personalized approach ensures that students remain engaged while learning at their own pace.

Gamification, the application of game-like elements in non-gaming scenarios, has proven effective in motivating students and enhancing the learning process. Teachers incorporate scoring systems, badges, leaderboards, and challenges into regular lessons. For instance, reading a certain number of books might earn a student a badge, or correctly solving math problems might give points leading to a leaderboard. This competitive yet supportive environment encourages students to take ownership of their learning. Gamification tools, such as Classcraft or Kahoot! have become popular in many schools. These platforms turn lessons into interactive experiences, where students can work in teams, answer questions, and earn rewards, making the learning process more engaging and enjoyable.

Schools across the country have started recognising eSports not only as a legitimate sport but also as a platform for skill development. Many Australian secondary schools now have their own eSports teams, participating in national and regional tournaments. While playing games, students learn about teamwork, strategy, communication, and analytical skills. Participating students often exhibit improved concentration, critical thinking and collaboration skills.

The principles of game design are included in an elective Digital Technologies Curriculum topic so the inclusion of eSports in schools has legitimate educational value. It also provides students with some of the skills that are required for careers in game design, broadcasting, event management, and even scholarship opportunities in universities that have their own competitive gaming teams.

While the integration of games and gamification offers numerous benefits, it is crucial for educators to strike a balance. Over-reliance on gaming mechanisms could detract from essential traditional learning experiences. Additionally, the risk of screen addiction and ensuring that content is age-appropriate are concerns educators must address. However, with careful planning and a balanced approach, computer games, gamification, and eSports can significantly enrich the Technologies curriculum.

6. Using digital learning tools for collaboration

Australian schools have been at the forefront of incorporating collaborative digital tools into their curricula. Rather than use digital technologies to run drill-and-practice programs, or have students focussed on individual tasks, Australian teachers have a preference for group work. Collaborative technologies enable teachers and students to share presentations, worksheets, classroom resources, assessment tasks and communicate via collaborative tools. These tools not only enhance learning outcomes but also promote the development of 21st-century skills (Jefferson & Anderson, 2017).

While Learning Management Systems (LMS) like Google Classroom, SeeSaw, Canvas, Microsoft Teams, Moodle or Edmodo are now common in both Australian primary and secondary classrooms, it is the widespread adoption of cloud-based platforms such as Google Workspace for Education and Microsoft that have had the largest role in working collaboratively. Google Docs and Microsoft Word Online, for instance, have become essential tools, allowing multiple users to work on a single document simultaneously. This concurrent access means that students and teachers can collaboratively edit, comment, and provide peer feedback in real time, streamlining the group work process and encouraging interactive learning.

Assignments can now be distributed digitally, and students can submit their work back via the same platform. Teachers can then annotate, provide feedback, or grade assignments directly within the document, creating a centralized and organized workflow. The immediacy of this feedback loop ensures that students understand their mistakes and can make revisions more promptly.

Moreover, digital portfolios have grown in prominence, allowing students to create, curate, and share their work over time. Platforms like Seesaw offer students a space to document their learning journey, share it with their peers, teachers, and even parents, emphasizing reflection and continuous growth.

Most schools also allow limited parental access to these platforms so they can keep abreast of their children's workload requirements.

One of the benefits of this sharing-centric approach is the development of the skills required to be addressed as part of the Digital Literacy Capability which includes addressing online etiquette among students, including respecting others' contributions, understanding version histories, and managing digital permissions.

However, with the increased capability to share, concerns about online safety and integrity arise. The Digital Literacy Capability (ACARA, 2022c) addresses this content to promote a safe digital environment. It is the requirement that teachers ensure students, at all school levels, are familiar with the ethics of digital sharing, avoid plagiarism and understand the privacy of personal information.

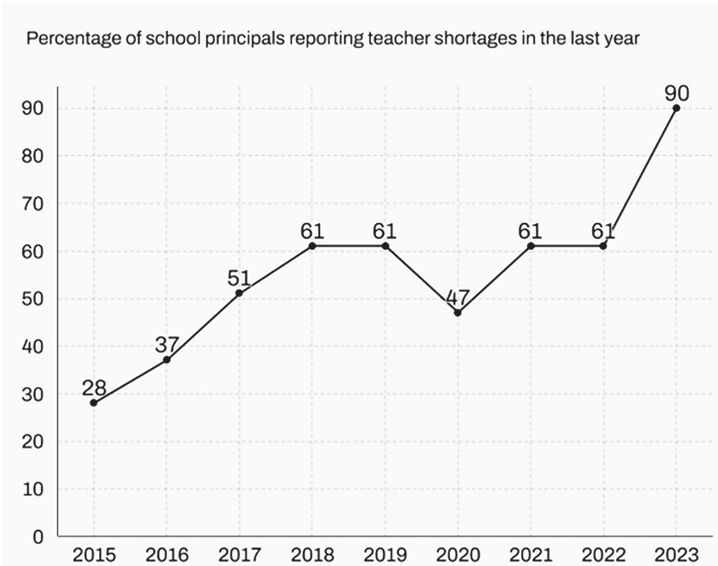
Teachers have found that the inclusion of collaborative digital tools has led to a more efficient, convenient, inclusive, and transparent educational experience.

Issues in Digital Learning

1. General teacher shortage

In 2023, the Australian Government Department of Education predicted that there would be a shortfall of 4,100 secondary school teachers by 2025. This shortage is already being felt in schools across the country, with many schools reporting difficulty filling vacant teaching positions (see Figure 3).

Figure 3 AEU State of Our Schools Survey 2023



Note. Australian Education Union, 2023; Cited in 'Investing in Australia's Future: For every child, fully funded public schools'

Secondary schools are currently experiencing more teacher shortages than primary schools. This is due to a number of factors, including the higher turnover rate of secondary school teachers and the increasing demand for teachers in STEM (Science, Technology, Engineering and Mathematics) subjects. The situation for Technology teachers is dire in all Australian states and territories. However, schools in rural, regional and remote areas are experiencing more severe teacher shortages due to the difficulty in attracting and retaining teachers in areas with more limited services.

The issue is being exacerbated by a number of factors (Kuestenmacher 2023), including:

- Declining numbers of new graduate teachers: The number of students entering initial teacher education (ITE) has been declining in recent years.

In 2022, the number of first preferences for education degrees was down 19.24% from 2023, the lowest rate since at least 2016.

- Increasing demand from a growing student population: Australia's student population is projected to grow by 11% between 2021 and 2031, putting further strain on the teacher workforce.
- An ageing teacher and leadership workforce: More than a third of all registered teachers in Australia are aged 50 years and over. This means that a significant number of teachers are approaching retirement age, and there is a need to attract and retain new teachers to replace them.

The teacher shortage is currently having a number of negative consequences for Australian schools (Kuestenmacher, 2023), including:

- Teachers are having to work harder to cover for vacant teaching positions. This is leading to burnout and a decline in the quality of teaching.
- Schools are having to increase class sizes to cope with the teacher shortage. This can make it difficult for teachers to provide individualized attention to their students.
- Schools may have to reduce the number of subjects or programs they offer due to the teacher shortage. This can limit students' learning opportunities. Fewer Senior High School elective Technology classes are being offered in 2023 and teachers report it is not due to a drop in student interest but a lack of qualified teachers able to teach at this level.

The Australian Government is taking a number of steps to address the teacher shortage (Kuestenmacher, 2023), including:

- The Australian Government is providing scholarships to increase the number of students entering Initial Teacher Education (ITE) programs in universities.
- The Australian Government is working with state and territory governments to improve the salaries and working conditions of teachers.

- The state and territory governments are offering financial incentives and other support measures to attract and retain teachers in rural and remote areas.

Despite these efforts, the teacher shortage is likely to remain a challenge for Australian schools in the coming years. Being a knowledge-driven economy, Australia needs to uphold the standard of its education system. Encouraging talented, skilled and enthusiastic individuals to pursue teaching careers is a crucial step in preparing the country for the future (Kuestenmacher, 2023).

2. The need for teacher professional development

Many teachers did not grow up using digital technologies in the same way that their students have and consequently they are not always confident in their own digital skills. As digital learning becomes increasingly ubiquitous in Australian classrooms, there is a growing demand for teacher training programs that can help teachers to confidently integrate digital technologies into their teaching practice. Even those who were formally trained in digital learning can find it difficult to keep up with the rapid pace of change in the field (Zagami, 2022).

According to a recent survey by Seven Steps (2023), a leading provider of teacher professional development, 92% of Australian teachers believe that digital learning is important for their students, and 83% said that they would like more professional development on the topic. Despite this, higher proportions of Australian teachers, compared to the OECD average, indicated that they had received training in teaching in the use of digital learning in teaching (ACER, 2018).

There is a growing body of research that supports the implementation of ongoing teacher training programs for digital learning. For example, a study by the Australian Council for Educational Research (ACER, 2023) found that teachers who participated in digital learning training programs were more likely to use digital technologies in their teaching practice and to report positive outcomes for their students. Some of the key areas teachers state they need further training in include:

- The integration of digital technologies in teaching and learning activities
- The development of digital learning resources
- The assessment of digital learning
- The management of digital learning environments
- The ethical use of digital technologies in schools

This research demonstrated that the potential benefits of teacher training programs for digital learning are significant. By providing teachers with the skills and knowledge they need to use digital technologies effectively, these programs can help to improve student learning outcomes.

In addition to the topics listed above, demand for teacher training programs for digital learning is increasing in topics such as:

- Using artificial intelligence tools in the classroom
- The use of social media in education
- How to leverage mobile learning
- Fully utilizing digital collaborative tools
- Using virtual reality and augmented reality in education
- Realising the potential data analytics in education

These topics are becoming increasingly important as digital technologies continue to evolve. By providing teachers with training on these topics, teacher training programs can help teachers to stay up to date with the latest trends in digital learning.

The Australian government is taking steps to support teachers in developing their digital learning skills by funding the development of several digital learning resources and tools for teachers' professional development programs for teachers on digital learning, some of which have been outlined earlier in this chapter. Both the various governments and individual schools need to play a role in supporting teachers in developing their digital learning skills so that they can provide their students with the best possible education.

3. Uneven access to digital learning – the digital divide

The digital divide refers to the gap between students who have the devices and internet access they need to learn online and those who do not. This gap can have a significant impact on student outcomes, as students without access to digital learning infrastructure may be unable to complete their schoolwork, participate in class activities, and/or access online resources.

The digital divide can manifest in a number of ways. Students from low-income families are less likely to have access to a computer or tablet at home, those living in rural areas may have difficulty accessing reliable internet service, and students with disabilities may need specialised hardware or software that is not available to them. Students who feel like they are falling behind academically are more likely to drop out of school, which then limits their opportunities for future education and employment.

The digital divide became particularly apparent in Australia during the COVID-19 pandemic, as many schools shifted to online remote learning. Students without access to digital learning infrastructure were at a significant disadvantage during this time.

While the technological infrastructure in Australian schools for digital learning is on a positive trajectory (Thomas et al., 2023), there is still some work to be done to ensure that all students have access to the resources and the support they need to succeed in a digital world. Even now, some schools in rural and remote areas have limited access to high-speed internet (NSW Dept of Education, 2023; Queensland Audit Office, 2023).

It is important to address the digital divide so that all students have the opportunity to succeed in school and in life. While the Australian Government has a number of initiatives in place to address the digital divide, such as the 'Schools Broadband Initiative' (ADDMC, 2022) and the 'Digital Inclusion Program', the statistics below illustrate more needs to be done to ensure that all Australians have access to the digital tools and skills they need to succeed.

- 11% of Australians do not have a smartphone (Deloitte, 2019).
- 16% of Australians have difficulty using the internet (ACMA, 2020).
- 22% of Australians do not have access to a fixed broadband connection (ACMA, 2020).
- 34% of Australians in the lowest income quintile do not have a home internet connection (ACMA, 2020).

These statistics show that the digital divide is a significant issue in Australia, and one that is important to address so all Australian students have the opportunity to participate fully in their classroom activity.

4. Community push back against digital technologies use

Australian parents and community members are starting to push back against the use of digital devices in schools and pre-schools for a variety of reasons (Gonski Institute for Education, 2020; Royal Children's Hospital, 2021), including:

- Australian children spend an average of seven hours per day in front of screens, and this can lead to a variety of health problems, including obesity, sleep deprivation, and eye strain.
- Digital devices can be a major distraction in the classroom, making it difficult for students to focus on their work.
- Digital devices can make it easier for bullies to target their victims, both

inside and outside of school.

- Schools often collect a lot of data on students' digital activity, and parents worry about how these data are being used and protected.
- Digital devices can make it easier for students to cheat on tests and assignments.
- Digital devices can discourage face-to-face interaction between students, which is important for their social and emotional development.

In addition to these general concerns, some parents and community members also have specific objections to certain types of digital devices or educational software. For example, some parents worry that the use of tablets and smartphones in the classroom can lead to addiction. Others are concerned about the use of educational software that tracks student data or uses artificial intelligence to personalize their learning.

It is important to note here that research that suggests that digital learning enhances learning continues to grow. For example, recent studies have shown that utilising digital learning can help students to develop their critical thinking skills, creativity, and problem-solving skills (Ibrahim et al., 2021; VanSickle & Rupp, 2020). However, this research also suggests that digital devices should be used in moderation and in a way that is aligned with learning outcomes.

While the Australian government continues to invest in the use of digital devices in schools, the need to address parental concerns has been recognised. In 2020, the government released a 'Digital Education Strategy' which outlined several ways to address the risks associated with the use of digital learning in schools. These include:

- Providing training for teachers on how to use digital devices safely and effectively in the classroom.
- Developing resources for parents on how to manage their children's use of

digital devices at home.

- Working with industry partners to develop safe and effective digital educational products and services.

The Australian government is also developing a national online safety strategy for schools. This strategy aims to protect students from online harm, including cyberbullying, online predators, and inappropriate content. Extensive educational resources have been developed on the eSafety Commissioner's website (eSafety Commissioner, 2023). The eSafety Commissioner is the world's first government agency dedicated to keeping people safer online.

At this stage it is not clear what affect these actions will have on the parental and community resistance to device use in Australian schools, but it will be a space to watch in the coming years.

5. Lack of engagement with digital learning by Australia's First Nations students

Australia's First Nations students are less likely to engage with digital learning and technology than their non-Indigenous peers. This is due to a number of factors (Department of the Prime Minister and Cabinet, 2020; Robinson & Bidwell, 2019), including:

- First Nations students are more likely to live in remote communities with poor internet access and limited availability of devices. This can make it difficult for them to participate in digital learning activities.
- Some First Nations students may be reluctant to use digital technologies due to cultural factors. Some communities may place a higher value on oral storytelling than on written communication.
- Much of the digital learning content available in Australia is not culturally relevant to First Nations students. This can make it difficult for them to engage with the material and see how it relates to their own lives.

- Not all teachers in Australia are trained to teach using digital technologies in a culturally responsive way. This can lead to First Nations students feeling alienated and excluded from digital learning activities.

There are a number of things that can be done to address the lack of engagement with digital learning and technology by First Nations school students (Department of the Prime Minister and Cabinet, 2020; National Indigenous Australians Agency, 2020). These include:

- Governments and schools need to invest in improving access to devices and internet in remote communities. This could include providing free or subsidized devices to students and installing Wi-Fi hotspots in public places.
- More needs to be done to develop culturally relevant digital learning content for First Nations students. This might involve working with First Nations communities to create content that reflects their culture and values.
- All teachers need to be trained to teach using digital technologies in a culturally responsive way. For example, providing training on how to use digital technologies to teach Aboriginal and Torres Strait Islander culture and history, and how to create culturally relevant digital learning resources.

The lack of engagement with digital learning and technology can limit First Nations students' access to educational resources, hinder their learning outcomes, and disadvantage them in the job market. However, it is important to note that there is no one-size-fits-all solution to the issue of lack of engagement with digital learning and technology of Australia's First Nations school students. What works for one student may not work for another. It is important to consult with First Nations communities and students to develop solutions that are tailored to their specific needs.

Conclusion

The Education Goals for Young Australians (Australia Council, 2019) emphasize excellence, equity and the development of confident and creative individuals. Achieving equity in digital learning in Australia's classrooms has been challenging. Digitalization is well-established in the Australian education system, with technology playing a vital role in classroom education, administration and communication. Most Australian teachers actively employ digital technologies to enhance learning and prepare students for a connected world.

Several features differentiate Australian digital learning from many of its OECD counterparts. A national curriculum mandates technology and digital literacy education for all Australian students, with the goal of ensuring consistent experiences with digital learning from Foundation to Year 8 or 10. Emphasis is placed on online safety and digital citizenship education, addressing protection from online harm and responsible technology use, and coding and problem-solving skills are integrated into the curriculum, acknowledging their importance in an increasingly technological world.

Current trends in digital literacy in Australian schools include widespread technology integration, the growing significance of digital learning, STEM education and the increased use of artificial intelligence tools. These developments offer benefits but also raise concerns about overreliance on technology. While digital learning offers flexibility, it also requires high-quality programs and support. Artificial intelligence tools may assist in this and in other related areas of digital learning.

However, a number of issues threaten the future of quality digital learning in Australian schools. A predicted shortage of school teachers poses a challenge to maintaining education standards. The digital divide affects disadvantaged students' access to digital learning resources and impacts their outcomes, and some parents and community members are concerned about digital device use in schools, prompting the government to work on a national online safety strategy.

In conclusion, Australian education utilises digital learning and online safety education, while striving for excellence and equity. However, challenges such as teacher shortages, the digital divide, and First Nations students' engagement must be addressed if the stated Education Goals for Young Australians (Education Council, 2019) of excellence and equity are to be met in the future.

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Trends and Issues of Digital Learning in Estonia

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Abstract

Estonia is a country with a high level of digital readiness and good student achievement in international comparisons. This increases the responsibility of Estonian educational technology researchers to study the use of digital technologies and to suggest directions for improvements, as the Estonian case could be a valuable example worldwide. In this chapter, the authors aim to provide an overview of the Estonian education system and strategic directions for empowering teachers and students in schools with meaningful digital learning and teaching approaches. The Framework for the Digital Competence for Learning and Teaching developed by the authors highlights the need for transformative digital competence in addition to generic and contextual competences. This highest level of digital competence is necessary to advance from the Digitization of education to the Digital Transformation stage. Currently, the results of the DigiEfekt study show that Estonian teachers focus mainly on the constructive use of digital technologies and do not usually provide students with interactive assignments that would foster collaboration. The study also reveals that technology tends to be used as a substitute for traditional learning processes, that is, those not involving technology, or, less often, for the augmentation of learning. Thus, modification and redefinition of the whole learning process and learning goals does not really seem to be the case in Estonian schools. Teachers' main goal for using digital technology in the classroom appears to be practical enhancement; qualitative enhancement has received much less attention. Therefore, it is important to focus more on teachers' professional development activities that have an effect on their mindset and result in a critical revision of their goals and practices. The Educational Technology master's program introduced in this chapter is one good example of the desired programs. However, to scale such programs up to involve all schools, learning communities should be established and supported in schools.

Keywords: digital competence, educational technology, DigiEfekt, Estonia

Introduction

Estonia has been branded as a "digital education nation" (see Forsman et al., 2023; Mehisto & Kitsing, 2022). This is based on two sets of analyses, one describing country level comparisons of digital readiness and the other the academic achievement of students in Estonia. For example, according to the Index of Readiness for Digital Lifelong Learning developed by the Jobs & Skills Unit at the Centre for European Policy Studies (CEPS), Estonia is ranked as the country with the best digital readiness among the 27 European Union countries included in the analysis (see Beblavý et al., 2019). However, in the World Digital Competitiveness Ranking list developed by the International Institute for Management Development (IMD), Estonia is not at the top – in 2022, Estonia was in 20th place among the 63 countries included in the comparison (IMD, 2022). Another example that is directing us to ask additional questions is from the Teaching and Learning International Survey (TALIS), which focuses on teachers, teaching, and learning environments. According to the survey, only 29.7% of Estonian teachers feel prepared for the use of information and communication technologies (ICT) for teaching (see https://www.oecd.org/education/talis/talis-2018-compare-your-country.htm). Of course, this result might be explained by the rather self-critical stance of Estonian teachers compared to several other countries where teachers might overestimate their digital readiness; however, it still clearly demonstrates that there are several challenges to be faced in the Estonian context to support digital learning in Estonia. Thus, it could be concluded that according to the framework for digital transformation introduced by Luo and Wee (2021), Estonian schools and teachers have long passed the Digitization stage, but for some reason, they are stuck in the stage of Digitalization without advancing to the Digital Transformation stage. This chapter aims to shed some light on the possible reasons, and to suggest some ideas for moving forward.

The academic achievement of Estonian students is often compared with other countries based on the Program for International Student Assessment (PISA). According to PISA results, Estonia is among the ten best countries in the world in all three dimensions covered: math, science and reading skills (see https://gpseducation.oecd.org/CountryProfile?primaryCountry=EST&treshold=10&topic=PI).

However, every medal has two sides, not just the bright one. According to the same PISA study, students in Estonia seem to exhibit some of the lowest levels of positive feelings, ranking 64th out of 69. This might also be one of the reasons for their weak interest in studying further and pursuing a career related to math, science or languages. As a result, there is a significant shortage of teachers (PISA ranking 6 out of 78), especially in math and science. Teachers therefore need to find smart solutions for sustaining the quality of education in a situation of high workload due to the increased number of students in classes and having more lessons per week to provide high-quality education to all children. Digital tools can be of great value in assisting teachers with planning, guiding, monitoring and giving feedback. Also, they can support students in various self-regulation processes, which are of paramount importance. For example, a recent survey investigating Estonian K-12 teachers' expectations related to Artificial Intelligence provided important insights into the major areas of concern (see Chounta et al., 2022). When asked what they would focus on if they could have a superpower at their disposal, Estonian teachers mentioned as priorities effectiveness, efficiency, rapport with students, course planning, personal attributes and personal skills. This shows that teachers see a great deal of potential in digital learning, but this dream has not yet come true.

In conclusion, it can be said that Estonia's education system has several remarkable results in international comparisons, and this increases our responsibility in educational innovation and related research. At the same time, our teachers and students are facing their own challenges, leading to the point where teachers do not feel competent in digital learning, which might also affect students. The following sections offer an introduction to the Estonian education system and outline the authors' views on the digital competence required for digital learning and teaching. After that, two cases are shared that illustrate how students and teachers are implementing digital technologies in Estonian K-9 education, and how the authors have contributed to the professional development of educators. More specifically, the former is done based on a large-scale national study called DigiEfekt, and the latter is based on the authors' experience in the Educational Technology master's program supporting educators' outlook on digital learning and teaching. For the discussion, these examples are linked to the framework for digital transformation to identify trends and issues in digital learning.

Education in Estonia

The Estonian education system supports the lifelong learning approach. This means that structures have been created that enable learning throughout one's life. Most Estonian children attend kindergarten, although it is not compulsory. Formal and compulsory schooling starts at age seven and lasts for nine years in basic school, which is divided into three levels, each lasting three years. Teachers at the primary school level usually teach most of the subjects themselves, which lends a lot of flexibility to integrate various subject areas. Often, students do not get numerical grades at this level, but supportive constructive feedback. Starting from grade 5 or 6, different subjects are usually taught by subject-specific teachers: e.g., science (or from grade 7 or 8, there are separate courses for biology, geography, physics and chemistry) is taught by a teacher who is a graduate of a science program and has completed a teacher education program after that or in parallel. After graduation from basic school, at age 15 or 16, students usually continue their studies – either in a secondary school (general educational studies, mainstream among the students) or in a vocational education school (where the program consists of both general and vocation-specific courses). However, vocational education schools also offer programs for those who do not aim for a certificate of secondary education. When the certificate of secondary education has been awarded, however, it does not matter if it is from a general secondary education focused school or from a vocational education oriented school. In both cases, students graduate with a degree that allows them to continue their studies in higher education, in either universities or other higher education institutions. What is more, according to the goals of the recent Education Strategy of Estonia, general and vocational education are expected to merge even further in the coming years. In higher education, three levels are distinguished: the first ends with graduation at the baccalaureate or an equivalent level, the second at the master's or equivalent level, and the third at the doctorate level. An overview of the Estonian formal qualifications system is given in Figure 1.

Figure 1 Estonian Formal Qualifications Framework

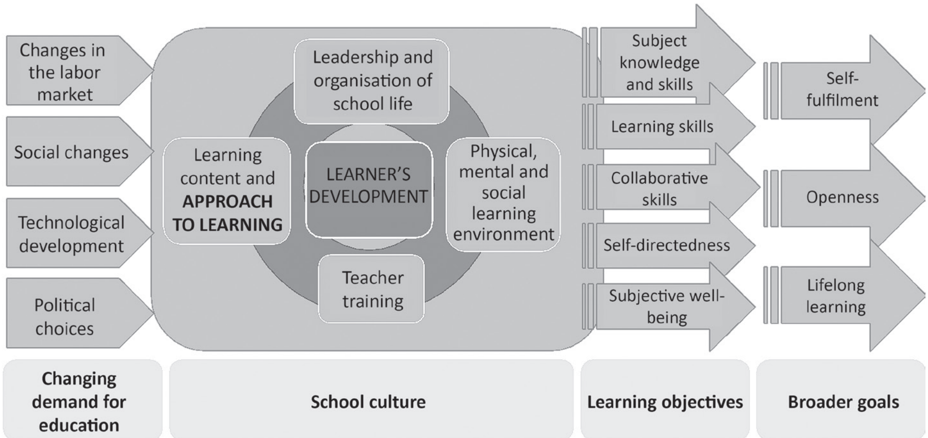
Estonian Qualification Framework Level	Qualification			
8	Doctoral Degree			
7	Master's Degree	Degree in Medicine	Degree in Dentistry	Degree in Veterinary Medicine
6	Bachelor's Degree			
5	Certificate of Specialized Vocational Education			
4	Certificate of General Secondary Education	Certificate of Vocational Secondary Education	Certificate of Vocational Education Level 4	
3	Certificate of Vocational Education Level 3			
2	Certificate of Basic Education	Certificate of Simplified Basic Education Program	Certificate of Vocational Education Level 2	
1	Certificate of Moderate Learning Disabilities Program			

In the Estonian context, the education system is considered the country's key means of building its national identity and developing society (see Jürimäe, 2022). It has been so for centuries, and it has not changed. In the times of occupation, the education system helped people maintain their identity and the Estonian language. The education system has enjoyed a considerable amount of autonomy throughout history. Teaching and learning in schools is mainly guided by the national curriculum and teacher professional standards. The national curriculum consists of a general part and subject-specific curricula (see Põhikooli riiklik õppekava, 2023). The general part defines the basic values of education, general goals and eight generic competences, including digital competence. In addition, there is an introductory part related to the concept of learning (e.g., focus on outcomes, adaptation to learners' characteristics, application of contemporary learning approach), learning environment (where mental, social and physical aspects support the development and learning process) and expected learning outcomes at the end of different study levels. Finally, there are several paragraphs defining formal regulations, for example, how many classes there are for different subjects, how parents are informed of their children's progress, how assessment is organized, and what the requirements are for graduation. The subject-specific curricula define mainly learning outcomes and integration of different subjects. The outcomes consist of knowledge, skills and attitudes. However, a great deal of autonomy has been left to teachers. They decide how to achieve the expected learning outcomes: what methods to use, how much time to spend on a topic, when to use digital technologies, or where and how to conduct lessons (e.g., in school, in a museum or as outdoor activities).

Teacher professional standards regard teachers as learning professionals who should continuously keep their teaching competence up to date (see Pedaste et al., 2019). In addition, it is expected that they contribute to the development of the teachers' community, at least at their school, but preferably at the regional and national level as well. The standards are designed to support teacher autonomy and authority based on their commitment and integrity. This means that there are specific standards for teachers, senior teachers and master teachers to support their professional development. In all of them, six compulsory competences are listed: (1) supporting the learner, (2) planning learning and teaching activities, (3) teaching, (4) reflection and professional development, (5) collaboration and counselling, and (6) research and development and creative activities. Moreover, there are 11 competences that are linked to all compulsory competences, for example, using correct language, creating a positive atmosphere, following professional ethics, collaboration, and digital competence. Finally, there are two elective competences, one of them focusing on digital pedagogy – how to create digital learning materials that could be used by other colleagues as well, how to lead and contribute to the analysis of digital infrastructure at the institutional level, and how to support curriculum development with the integration of digital technologies. According to Pedaste et al. (2019), these standards are successfully used to design pre-service education and award teacher certificates at the end of the higher education studies (all schoolteachers in Estonia are required to have a master's degree). However, the standards have less of an impact on the regular assessment of in-service teachers' competences and the design of professional development plans.

Besides the national curriculum and teacher professional standards, educational practices in Estonia are guided by national strategies, for example, the Estonian Education Strategy 2021–2034 (2021). According to that document, the general objective of the Estonian education system is "to equip the population of Estonia with the knowledge, skills and attitudes that prepare people to fulfil their potential in personal, occupational and social life and contribute to promoting the quality of life in Estonia as well as global sustainable development" (p. 2). Three strategic goals are specifically defined: (1) to provide diverse learning opportunities and enable a smooth transition between levels and types of education, (2) to support the competence and motivation of teachers and heads of schools so that the learning environment would be learner-centered, and (3) to ensure flexibility and responsiveness of the learning options according to the needs of society and the labor market. More specifically, a framework for contemporary learning has already been created based on the previous version of the national education strategy (see Õpikäsitus, 2017). According to this (see Figure 2), there are three general broader goals for the learning process: self-fulfillment, openness and lifelong learning capability. However, these have been considered too broad and vague to be assessed. Therefore, more specific learning objectives have been defined: subject knowledge and skills, learning skills, collaborative skills, self-directedness and subjective well-being. These should be considered by all teachers in the learning and teaching process, including activities with digital technologies. On the left of the figure, it is explained why we need to regularly consider changes to our learning approach – it is because of changes in the labor market, social changes (like the current situation of increased numbers of refugees), technological development (like the recent rapid advancements of AI based tools in education) and political choices. In the middle of the framework lies school culture, serving as the "mediator" between demands on education and expected learning goals. At the center of the school culture stands the learner or, more specifically, their development, which is supported by the leadership, environment, teacher training, learning content and approach to learning.

Figure 2 Framework for the Contemporary Learning Approach in Estonia



Note. Based on Õpikäsitus, 2017.

Digital learning is directly linked to various elements of the contemporary learning approach. For example, changes in the labor market increase the demands on computational thinking and use of existing digital technologies in different professions. Social changes set the demand for effective communication with people who do not speak the language of instruction of a school, for example, in the case of refugees who speak only Arabic or Ukrainian or other languages not spoken by the teachers or peers. Technological development has provided us with AI-based tools such as ChatGPT, and there is an ongoing hot debate worldwide, Estonia being no exception, about the need to integrate AI into the learning process, or to set restrictions on its use in learning and assessment. One of the political choices made by the Estonian Ministry of Education and Research related to digital learning is the adoption of digital learning goals and, more broadly, smart specialization goals in their strategic documents. A conspicuous amount of money from the Estonian state budget and European structural funds has been allotted for building the structures and providing education that would help society benefit from digital technologies in the teaching and learning process and in many other areas.

In the context of school culture, practically all Estonian schools have adopted a Learning Management System that not only allows smooth communication between teachers, the school leadership team, students and parents, but also enables students to upload their coursework, give and receive feedback, interact with learning materials, including those consisting of rich media, and so on. Often, schools have identified digital competence, in one way or another, as a goal in their strategic development plans. What is more, this is also true for kindergartens. Usually, schools and kindergartens have no significant technical limitations in terms of hardware, software or internet connection, which means that the use of digital technologies comes down to the teacher's willingness to invest time in learning how to use them meaningfully. One of the main challenges hindering educational innovation seems to be teachers' workload, which is considerably high due to the shortage of teachers. In this situation, teachers only have limited time to invest in continuous professional development, although international comparisons show Estonian teachers quite actively participating in various in-service courses. Professional development activities for teachers are normally provided by the universities that are also responsible for pre-service teacher education. In a small country like Estonia, all processes tend to be connected, which results in a very closed system – it is the same people who contribute to the development of the national strategies, national curriculum, teacher professional standards, pre-service and in-service teacher education programs, national testing of the learning outcomes or school satisfaction, and research related to the above-mentioned topics. Another challenge related to this situation is that some of the university staff members are heavily overloaded and cannot delve into topics in any great depth. In some cases, this has also resulted in burnout, and sometimes it is difficult to recruit new staff.

In the context of learning objectives, all five listed in Figure 2 are related to digital learning. For example, many digital learning materials have been developed in Estonia or have been translated to acquire subject knowledge and skills. A large collection of the materials has been systematized and made freely available to all teachers and students through an online repository called eSchool bag (see https://e-koolikott.ee/en). In this environment, teachers can reuse the existing learning materials, adapt them to their specific needs, or create new ones. The variety of the learning materials is also quite rich: videos, presentations, games or simulations, tests, studies or projects, guides, knowledge testing, exercises or worksheets, textbooks, courses or texts, lesson plans, sources of information, sounds, and images. As of May 2023, there were almost 2,000 different learning materials. In addition, teachers actively use learning materials developed in several international projects in which Estonian researchers have actively collaborated, e.g., Go-Lab (see https://www.golabz.eu/; de Jong et al., 2021), WISE (see https://wise.berkeley.edu/; Linn et al., 2003), Ark of Inquiry (see https://arkportal.ut.ee/; Pedaste et al., 2015), and PhET (see https://phet.colorado.edu/; Wieman et al., 2008).

Learning skills, collaborative skills, self-directedness and well-being are also tightly linked to digital learning. It means that schools focus on learning strategies in digital learning environments, including those for collaborative learning activities. In 2020, due to COVID-19 related closures, schools were forced to switch to online and hybrid learning. This was not unfamiliar to schools. Most of them were ready to face the emergency because they had already experimented with online learning during the so-called e-learning days, when students got their assignments and learned on their own at home while teachers were focusing on something else, such as their own professional development or development of strategic plans for the school. The studies conducted by Lepp et al. (2021), Rannastu-Avalos and Siiman (2020) and Adov and Mäeots (2021) showed how teachers flexibly adapted to the emergency. Lepp et al. (2021) showed how teachers' teaching-related decisions depended on the existence of digital tools and the ability to use them purposefully by students at home. Short-term goals, such as maintaining students' social interaction and supporting student motivation, became the leading factors in their decision making. Thus, students' well-being was highlighted more explicitly than before COVID-19. More specifically, Adov and Mäeots (2021) identified three groups of teachers who differed from each other in their willingness to use technology, change in their technology use from pre-COVID to distance learning, and variety in their use of technology. In addition, they identified several external (e.g., issues with the internet connection, lack of students' digital skills) and internal (e.g., teachers' beliefs about technology use for teaching) factors affecting teachers' decision making. Finally, they also noted students' poor digital skills as a limiting factor in designing a learning process for online learning in groups or self-regulated individual learning. Rannastu-Avalos and Siiman (2020) focused on science teachers and found that teachers mostly reported using video conferencing tools to engage in synchronous communication with students. Schools' learning management systems were mainly used for sharing information. They also found that the new distance education setting was challenging for collaborative learning. The DigiEfekt project, which started a bit later, showed that the same challenges persisted even after the end of the COVID-19 crisis, in the academic year 2021-2022.

Digital Competence for Learning and Teaching

As previously described, there are several challenges in Estonia when it comes to applying digital technologies meaningfully according to the contemporary learning approach, which guides educational decision-making in Estonia. One of the key factors of success in this context is digital competence. The first author of the chapter has proposed, together with several colleagues, a Framework for the Digital Competence for Learning and Teaching. It is based on a synthesis of mainly the ideas of Gallardo-Echenique (2015), Ilomäki et al. (2016), Krumsvik (2011), Martin (2009), Redecker (2017), and Spante et al. (2018). Redecker (2017) described the European Framework for the Digital

Competence of Educators (DigCompEdu). The framework defines six areas educators need to focus on to assess and improve their competence for teaching and learning: (1) professional engagement, (2) digital resources, (3) teaching and learning, (4) assessment, (5) empowering learners, and (6) facilitating learners' digital competence. This framework has been used in the Estonian context to support teachers' professional development, and is used as a basis for teacher professional standards for guiding teachers towards the assessment and improvement of their competences. It is also in line with most of the dimensions of digital competence described by Gallardo-Echenique (2015), Ilomäki et al. (2016) and Spante et al. (2018) in their reviews for operationalizing digital competence in a broad or more specific context, for example, higher education. However, they do not focus on the interesting hierarchy of the dimensions of digital competence that was introduced by Martin (2009) and Krumsvik (2011). Martin (2009) differentiated three levels of digital literacy: (1) digital competence (skills, concepts, approaches, attitudes, etc.), (2) digital usage (professional/discipline specific application) and (3) digital transformation (innovation/creativity). The European DigCompEdu framework focuses on elements of the first two levels, but not explicitly on those of the digital transformation level. However, even the elements of the first two levels are not clearly distinguishable – there is no distinct line between generic and contextualized knowledge, skills and values necessary for performing successfully in the digital learning process (see Pedaste et al., 2022). Krumsvik (2011) differentiated the levels of digital Bildung. He described the increase in self-awareness and practical proficiency through phases of adoption, adaptation, appropriation, and innovation. Similar to Martin's (2009) framework, teachers and teacher educators, the particular focus of that framework, should move from usage of the existing digital technologies to innovation – creative development of new ways of technology use through critical reflective thinking where all ethical aspects, sustainable development goals and other relevant principles are considered.

Inspired by the aforementioned discussion, the authors' Framework for the Digital Competence for Learning and Teaching identifies eight areas of competences, situated on three different levels (generic, contextual, transformative). Additionally, two different focus areas are singled out, namely, starting from the personal/individual competence and moving towards collaboration in a community of professionals for common good in the society, and considering the effect on the environment (Figure 3). In short, generic competence constitutes the ability to use technologies, related knowledge, beliefs and values, emotions as well as motivation towards digital technologies. Contextual competence, on the other hand, means contextualization of digital technologies and their use at the individual level and in collaboration with colleagues/peers. Transformative competence consists of creative adaptation of digital technologies in professional contexts and their ethical and responsible use. The framework could be further used for developing tools for assessing digital competence in different contexts and for designing interventions focusing on areas most in need of improvement. In this chapter, the framework guides the discussion of the cases introduced later.

Figure 3 Framework for the Digital Competence for Learning and Teaching

Focus on community/ society/environment	Transformative competence	8) Ethical and responsible (critical reflective) use of digital technologies
		7) Creative adaptation of digital technologies in professional contexts
	Contextual competence	6) Collegial contextualization in using digital technologies in particular contexts
Focus on individuals		5) Individual contextualization (planning, monitoring, evaluation and reflection) in using digital technologies in particular contexts
	Generic competence	4) Emotions and motivation towards digital technologies
		3) Beliefs and values towards digital technologies
		2) Knowledge (awareness and understanding) of digital technologies
		1) Abilities (skills) to use digital technologies, both hardware and software

More specifically, at the generic level, we are interested in the following:
Abilities: What is educators' proficiency in using digital technologies needed in the learning process? What is educators' proficiency in using digital tech-

nologies for assessment?

Knowledge: How well do educators know how to use digital technologies to promote learning?

Beliefs and values: What is educators' self-efficacy in using digital technologies? How confident are educators in creating digital learning environments? How do educators value digital technologies for learning? What are educators' attitudes toward the use of digital technologies (ease of use, usefulness and compatibility of technologies) in learning and teaching?

Emotions and motivation: What emotions do educators associate with the use of digital technologies? How motivated are educators to use digital technologies?

In the case of contextual competence, we are focusing on two aspects:
Individual contextualization: What are educators' goals in using digital technologies for learning and teaching? To what extent do educators support learners' use of digital technologies? To what extent do educators support the implementation of effective strategies for using digital technologies in learning? To what extent do educators express supportive pedagogical beliefs about the use of digital technologies?
Collegial contextualization: To what extent do educators learn from each other and mentor others in the contextual use of digital technologies? To what extent do educators collaborate with others in the contextual use of digital technologies? To what extent do educators reflect on the contextual use of digital technologies?

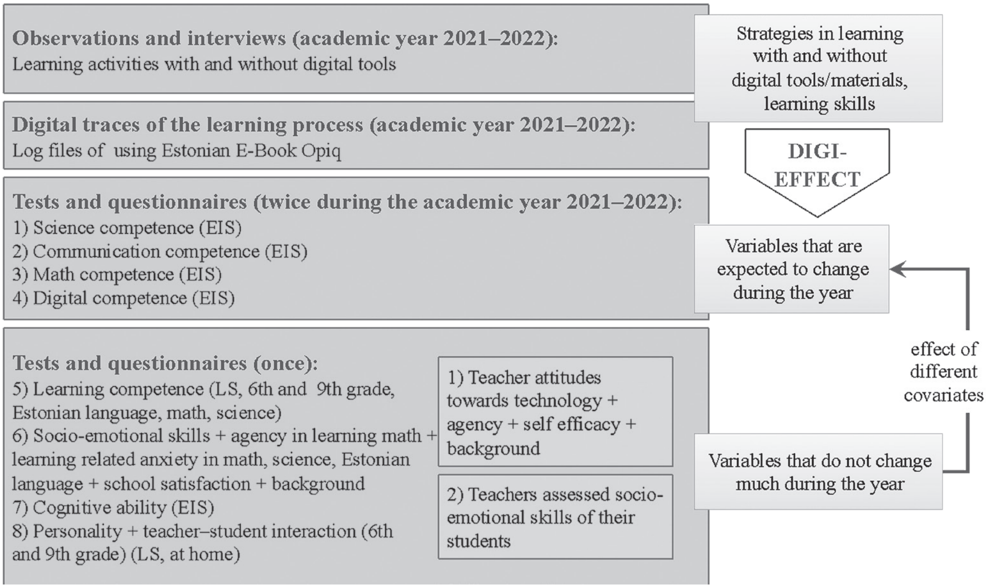
Finally, at the level of transformative competence, the following two dimensions are specified.
Creative adaptation: What is educators' competence for innovation? To what extent do educators express and apply innovation and an inquiry-oriented attitude in using digital technologies, and thus serve as role models for learners?

Ethical and responsible use: To what extent are educators role models for learners in the ethical and responsible use of digital technologies in their teaching? To what extent do educators raise ethical and critical issues related to the use of digital technologies and learning environments (e.g., in using social media or artificial intelligence)?

The Status of Digital Learning

Digital learning in Estonia can be described based on the large-scale study conducted in the DigiEfekt project. In this study, we focused on both students and teachers, and collected different types of data during the 2021-2022 academic year (see Pedaste et al., 2023). First, students' learning activities in math, science and Estonian language classes were observed, and teachers were interviewed right after the classes to understand their goals (see Figure 4). In addition, students' learning activities in a widely used collection of E-Books were logged. Finally, several tests and questionnaires were administered to describe students' competences and background information that should be taken into account in drawing conclusions about the effect of different learning strategies on both cognitive and non-cognitive learning outcomes, science competence, communication competence, math competence, digital competence, learning competence, and socio-emotional skills, in particular.

Figure 4 Design of the DigiEfekt Study



Digital technology integration in classrooms

The analysis of the observations and interviews revealed that 82% of 169 lessons in the 3rd, 6th or 9th grade consisted of some type of activities where digital technology had been integrated (Raave et al., 2022a). However, the data showed that the practices seemed to be rather limited. For example, according to Puentedura's (2006) framework distinguishing Substitution, Augmentation, Modification and Redefinition (SAMR), teachers mainly gave students tasks where digital technology was only employed in a substitutional role – 71% of activities were in this category (Raave et al., 2022b). Augmentation was evident for 33% of learning activities, and modification or redefinition for only 3% and 6%, respectively. More specifically, among the substitution activities, the most common was presenting the learning content on a large screen, which formed about half of the cases of digital technology use. Very often, various digital interactive learning environments were used, for example, Opiq (the largest Estonian collection of E-Books), Geogebra, Learningapps, Liveworksheets, Matific, Wizer.me, as well as several materials in Estonian. Video-based platforms (YouTube and Vimeo) or gamified testing systems (e.g., Kahoot!, Quizziz, Socrative, 99Math, JeopardyLabs, CrosswordLabs, PurposeGames) were also used quite often. There were some differences in using digital technologies between the 3rd, 6th and 9th grade and math, science and Estonian language classes. These were not remarkable, however.

In addition to the SAMR framework, observation data were analyzed based on the ICAP framework distinguishing interactive, constructive, active and passive learning activities (Chi & Wylie, 2014). According to the analysis, constructive activities were the most common, while the others were used with similar frequency (see Raave et al., 2022c). The ICAP framework states that interactive activities are more engaging and lead to better learning gains compared to constructive activities; constructive activities in turn are more engaging than active activities; and active activities are more beneficial than passive ones. Thus, the digital learning activities in Estonian classrooms are rather engaging, although less valuable passive or active learning also occurs on many occasions.

The analysis of teacher interviews revealed three categories of goals of digital technology integration (Raave et al., 2022b). First, teachers most commonly aimed to use digital technologies because of some practical reasons, for example, availability of appropriate content, students' easier access to learning tasks or content, and greater ease of monitoring the learning process and giving feedback. The other two aims, engaging students (e.g., triggering interest) and increasing the quality of the learning process (e.g., activation of pre-knowledge or deeper understanding or practicing routines), were slightly less common.

Teacher and student characteristics and environmental conditions affecting digital learning

The classroom digital technology integration practices might be mediated by teacher or student characteristics, but also by environmental conditions for applying digital technology. Therefore, we also analyzed those aspects. The analysis of teachers' digital readiness showed that, on average, there were no significant issues in applying digital learning (Pedaste, 2022). On a 4-point Likert type scale, 91 teachers were asked if they were restricted in their digital technology use by lack or inappropriateness of either digital devices, digital learning environments or digital content; in all cases, the average score was 2, meaning that they did not agree to being restricted by those factors. At the same time, they mostly agreed to having in their schools enough digital devices connected to the Internet, a good quality Internet connection, the necessary learning software, and sufficient technological and pedagogical knowledge and skills for applying digital technologies in teaching and learning. However, they did not agree to having enough time for planning and designing lesson plans involving use of digital technology. In addition, they also found that they were not sufficiently encouraged to use digital technologies – no incentives were provided by their schools. Despite the digital readiness supported by the availability of tools, content, and knowledge and skills needed, the teachers' attitudes towards using digital technologies for teaching and learning were not so positive. On a 6-point Likert type scale, the score for behavioral attitudes was 4.2, perceived control 4.4, and behavioral intention only 3.1. Thus, teachers often lacked willingness to use digital technology and preferred other formats of learning if possible, despite the fact that the environmental conditions did not appear to restrict digital technology integration.

In the case of students, we assessed their digital competence for learning based on a framework in which two higher-order latent variables were described: (1) attitudes towards digital device usage and (2) skills of using digital devices and behavior in digital learning environments (Pedaste, et al., 2023). More specifically, nine lower-order latent variables were distinguished: perceived control, behavior-related attitudes, behavioral intention, creation of digital materials, digital content programming, communication in the digital world, performing digital operations, legal behavior in the digital world, and protection of oneself and others in the digital world. The results showed that compared to their teachers, the students had more positive attitudes towards using digital technologies for learning in all three dimensions of attitudes measured. The most significantly more positive were students' behavioral attitudes; for example, they were not frightened of using digital devices, they were not nervous about using them, and they were not confused and did not experience difficulties when learning in digital environments. As for perceived control, it was higher for 6th- and 9th-grade students, but not for 3rd-graders. Behavioral intention was higher for students in all grades; however, there was a remarkable change, with an increase from the 3rd to the 6th grade and a decrease from the 6th to the 9th grade. In the skills and behaviors assessed, there was a significant increase in all competence dimensions from the 3rd to the 6th and from the 6th to the 9th grade. As expected, programming skills were not very good; however, it came as a surprise that two other dimensions, performing operations with digital tools and legal behavior in the digital world, also showed quite low average scores.

Mediation of technology use

One more topic of interest in the DigiEfekt project was students' technology use, both in general and in the context of learning. More specifically, the question was how technology use can be mediated by the rules and restrictions they have. It has been shown that schools have in fact placed many restrictions on the use of digital technologies (Puusepp & Pedaste, 2022). Sometimes, there are limitations on using computers or smartphones, and conditional restrictions (when and where one is allowed to use personal digital devices) are quite common. Moreover, it seems to be rather customary to have restrictions on the use of Wi-Fi – a usual practice is to have separate networks for teachers and students. At home, parents also mediate their children's technology use. Data were collected from both children and their parents, and the results turned out to be somewhat different. In general, children did not perceive having as many rules and restrictions as their parents reported. The most common were restrictions on using digital devices (e.g., how many hours a day, when or on what conditions their smartphones, tablets or computers could be used). In addition to that, three more categories of restrictions were specified: environment-related (e.g., restrictions related to YouTube, Facebook, Discord), content-related (e.g., restrictions related to different types of content and different activities with the content – downloading games or apps, rules of courtesy in online communication, age-specific restrictions), and Internet connection related (e.g., Wi-Fi or data volume related). The older the children, the fewer restrictions they had. In conclusion, it seems that the restrictions at both school and home were not so much related to digital learning as to the general use of digital technologies.

Professional development of educators' competence for digital learning

Educators' professional development for digital learning has been supported by several courses for pre-service and in-service teachers. However, at the University of Tartu, a special master's program has also been designed for all educators at different educational levels. The aim of the program is to give educators the chance to upskill themselves for a more meaningful use of educational technologies and for guiding others in revising their existing practices and doing research in the field. Therefore, it is a good example of how educators' competence for digital learning is supported in Estonia.

The Educational Technology master's program was officially launched in August 2017. Since its inception, the program, which is one year long, has been advertised as "almost fully online." The "almost fully online" refers to the fact that students and teaching staff members meet at the beginning of the academic year for an intense period of study lasting for about 10 to 12 days in the second half of August. After that, from September to its end in June, the study sessions continue in an exclusively online format. In this sense, the program meets the basic requirements to be considered a blended program, as it is a mix of traditional face-to-face learning with online learning (Alammary et al., 2014). While the term "blended learning" lacks a precise definition in higher education (Castro, 2019), in the context of the program, "blended" refers to the combination of classroom interaction with learning through thoughtful online activities, in which instruction can be differentiated from student to student.

The decision to have a blended format was justified in the light of providing an opportunity for adult learners to learn with and about educational technologies, which is the reason why the program became part of the postgraduate offerings at the University of Tartu. Currently, only those already with a master's degree or at least 5 years of experience in educational institutions are eligible. Additionally, the specific format was also meant to create an international community of people interested in educational technology, which, as we will see, has been one of the pillars of the program.

While in-service teachers have been the most represented category among the educational practitioners that the program attracted, throughout the years, the program has housed different profiles of practitioners such as human resource specialists, entrepreneurs in the field of educational technology, as well as coaches, university lecturers and even parents involved in homeschooling their children.

The curriculum of the program went through several rounds of development, which were also supported by the Erasmus+ project called "MA in Educational Technology: A New Online Blended Learning Program for New Member states" (Key Action: Cooperation for innovation and the exchange of good practices). During the project, which coincided with the first three iterations of the program (2017–2020), Utrecht University served as a partner during the curriculum development activities with a specific evaluation plan. The evaluation plan helped the teaching staff members and program director to identify areas of concern and development.

The current curriculum reflects the general approach to educational technology, which tries to integrate synergistically three main aspects:
(1) *theory* through the introduction of contemporary pedagogical frameworks with courses dedicated to problem-solving, self-regulation and the new learning paradigm, which includes digital competence frameworks;
(2) *practice* through the contextualization of educational technologies with courses such as "Technology Use in Education" and "Educational Design for Complex Learning Tasks;" and
(3) *reflexivity* through the development of a deeper understanding of the role of technology in education and society with courses such as "Critical Issues of Technology Use in Education."

In this sense, we may say that the curriculum reflects the idea of going beyond the two main approaches to educational technology, namely, the technology-led and pedagogy-led approaches. In line with the idea of entangled pedagogy (Fawns, 2022), the curriculum has a strong emphasis on the "contextualization" of digital technologies and the transformation of the teaching and learning practice through digital technologies.

In a survey that was distributed among former students at the end of 2020, the transformational impact of the program was highlighted. For example, one former student emphasized that "the program provided not only great content to learn, but for me the actual experience of how the sessions were organized is what I will use in my future practice." Another student referred to their study period as a fundamental experience to help their colleagues during the pandemic. Others stressed that the master's program allowed them to reach a "deeper integration of existing (and new) technology use in the workspace."

The emphasis on contextualization is also reflected in the design of assignments in the mandatory courses, which are tied to the students' own professional practice. This is supposed to facilitate the transfer of the learning to one's own practice, and to handle the intricate relationship between theory and study on the one hand and practice and work on the other. This is in line with the idea that blended learning combines what students learn with actual job tasks (Driscoll, 2002). For example, in some courses, students are supposed to conduct observational tasks in an authentic learning setting (e.g., a school), while in others, the final assignment is a project to be implemented in one's own professional setting.

As mentioned above, most courses are online and have activities that are both synchronous and asynchronous, with the flipped classroom as the main method used. The synchronous activities, namely webinars, are not organized as traditional online lectures but as discussions, which are introduced by a task to be performed before the webinar. The nature of the task may differ. It can be based on materials to be read, videos to be watched, or an activity to be performed in a group and/or at one's workplace. In some cases, those tasks are graded and count towards the final assignment. Incidentally, the fact that virtually all mandatory courses have webinars has been an important pedagogical cornerstone of the program in order not to lose the social and community aspect of learning, which has been one of the main pillars of the learning experience the program has contributed to.

The master's program is part of the postgraduate offer of the university. But what kind of profession does the master's program prepare for? Currently, the program does not provide any teacher qualifications. However, throughout the years, the program turned out to be particularly useful for three main categories of professionals. The first is those in-service teachers and university lecturers who want to transform their own teaching practice with the help of technology. The second category is composed of those who do not simply develop their own digital competence but want to help others do so and lead innovative processes in their own organization. In Estonia, this is the role of the so-called "educational technologist" (Lorenz et al., 2014; Bardone et al., 2020). The educational technologist, who is not to be mistaken for an IT specialist, has the main function of introducing digital technologies through workshops to teachers, assisting them in incorporating new tools into their own practice, and even creating a vision concerning educational innovation for the whole organization. In the aforementioned survey, one of the students remarked that they are now "much more able to support my colleagues in implementing technology into their classrooms. I am able to see opportunities where technology would be beneficial to myself, my students or my colleagues." Another student observed, "I feel much more experienced than my colleagues and I help them anytime." The third and last category comprises those who are interested in an academic career, in which the first step is enrolling in a doctoral program. In the last 5 years, more than a dozen graduates from the program have eventually started a doctoral degree in educational research in Estonia or elsewhere (e.g., the UK, the Netherlands, Latvia, the US). In the same survey, one student pointed out that the program gave them confidence and credentials to pursue a doctoral degree.

As anticipated, one of the pillars of the program is the community dimension that emerged around the formal teaching and learning activities, and constitutes a fundamental component of the blended learning experience that the students receive. The fact that the program is online with the sole exception of the 2-week onsite session at the beginning of the academic year in August allowed the emergence of a cosmopolitan community of learning and practice, which is now running parallel to the program. Over the past 6 years, virtually all continents have been represented. We have had students from Western and Eastern Europe, the Balkans, Scandinavia, the UK, Africa, North and South

America, Australia, and Asia.

Besides its multicultural nature, the community dimension has been one of the main elements praised by the students themselves. In a series of videos called “From the Horse’s Mouth” available on YouTube (https://youtube.com/playlist?list=PLxW5WmVB6QbnbIIIQ6tQ3IW-EhJOPk4bO), they were asked to reflect on their experience in the program. Students highlighted “the sense of togetherness” that emerged during their studies, which also involved the teaching staff members, who were seen as partners during their learning rather than mere gatekeepers. This sense of being together was an active part of the learning process. As one student remarked in one of the videos, “when we discover something we’re all very, very eager to share it with each other.” Others have singled out the connection with their cohort as “probably the most valuable thing I’m currently getting out of the program.”

As mentioned, the sense of being a community has grown parallel to the program itself, which has constituted some kind of catalyzer of interests. For example, over the past two years, several online events have been organized by former students with the specific intention of promoting educational technology. Such events included, for example, webinars concerning women in educational technology, the role of parents, democratic education, and so on. An online event called “EdTest Estonia,” which was meant to establish synergies between the private sector and educators, brought together 20 EdTech companies around the globe and 40 teachers.

Trends and Issues in Digital Learning

This section is devoted to taking stock of what has been presented so far, and discussing trends and issues in digital learning in Estonia. First, it seems that the infrastructure – not only digital devices and the Internet but also learning management systems and other learning environments – as well as content are available for digital learning. However, it appears that not enough attention is paid to collaboration and interaction of learners with each other or with the teacher, as demonstrated by Rannastu-Avalos and Siiman (2020) in their study based on a small number of teacher interviews, and corroborated by Raave et al. (2022c) based on the large-scale quantitative DigiEfekt study. According to the ICAP framework (Chi & Wylie, 2014), interactive assignments are more engaging than constructive, active or passive assignments. Thus, teachers' decisions to focus more on constructive assignments and to use a significant number of active or even passive assignments might have affected students' willingness to study using digital technologies. In the light of the recent developments, technology has even more affordances for interactive use, as ChatGPT and Natural-Language Processing (NLP) based solutions could at least partially replace or mediate human interactions in a dialogue-based interactive learning process. Good overviews of synergies between educational technologies and learning sciences have been presented by Linn et al. (2023) and Gerard and Linn (2022). They reported on cases where NLP-based technologies (e.g., visualization, collaborative tools and automated guidance) have been effectively used in scaffolding learners and supporting teachers in guiding their students in real time, and supporting them in a self-directed learning process. In the context of Estonia, Siiman et al. (2023) showed that ChatGPT responses to students' collaborative problem-solving assignments might be of better quality than those of human experts, suggesting that AI-assisted qualitative analysis has the potential to improve the learning process. Thus, there are good cases showing the benefits of digital technologies for fostering interactive digital learning, but it seems this has not yet entered the mainstream of Estonian schools.

Another finding worth discussion is that the learning goals of teachers in the digital learning process are mainly focusing on practical enhancement, but less on qualitative enhancement (Raave et al., 2022b). Practical goals of making the learning materials easily accessible and the learning process more visible for monitoring and giving feedback are certainly necessary; however, they might not be sufficient. It might be more important to focus on eliciting students' ideas, making them visible to other learners to start an active discussion; the active discussion would involve considering alternative ideas and later revising the learners' initial ideas in a guided reflection process, as described in the Knowledge Integration Framework (see Linn et al., 2003). Technology offers several affordances for activating pre-knowledge (e.g., mind-mapping tools or interactive collaborative online whiteboards) and organizing alternative ideas on idea-maps to learn from an interactive collaborative process. However, these innovative pedagogical ideas have not often been considered in the learning process, as revealed in the observations and interviews of the DigiEfekt project in the context of Estonia (Raave et al., 2022b).

The digital learning outcomes could also depend on the way of using technology. The results of the DigiEfekt project showed that teachers rarely modified or redefined their teaching and learning activities when using digital technologies (Raave et al., 2022b). It means that teachers tend to use the same methods in digital learning that they would use in a more traditional learning process that does not involve technology. In Estonian classrooms, digital technologies have been used mainly for substitution, and slightly less for augmentation. According to Puentedura (2006), these two ways of technology use are where the traditional learning goals and activities could be used in the new context of using technology. However, in addition to substitution and augmentation, it is also important to think about modification and redefinition if our aim is to harness the full potential of technology in a way that is meaningful for both learners and teachers. This might also lead to better learning outcomes, and not only better academic outcomes but also better non-cognitive learning outcomes, such as subjective well-being or socio-emotional skills.

Overall, the lack of interactive assignments, learning quality-oriented goals, and modification and redefinition of learning activities might be the reasons why students' attitudes are not very positive towards replacing other types of learning activities with those involving use of digital technologies. If teachers need to invest a lot of time in integrating digital technologies into the learning process and the students do not appreciate it, teachers' willingness to use digital learning also suffers. This might explain Estonian teachers' rather low scores on positive attitudes towards using digital technologies in the learning process, as demonstrated by the DigiEfekt study. The solution might be increasing the meaningfulness of digital learning. According to the authors' Framework for the Digital Competence for Learning and Teaching, Estonian teachers are mainly competent at the generic or contextual competence levels, but there are not many signs of transformative competence, that is, meaningful innovation of learning through use of digital technologies.

Thus, based on the frameworks of Martin (2009) and Krumsvik (2011), we can say that Estonian schools need digital transformation. Of course, there are good examples of meaningful technology use, but meaningfulness still rather appears to be a challenge in Estonian schools. This is reflected in students' behavioral intention to use digital technologies in different grades. While 6th-graders are more willing to use technologies compared to 3rd-graders, 9th-graders are less interested. This might be explained by the more critical viewpoint of the 9th-grade students: as their further admission to secondary schools depends on their results, the stakes are higher for them when it comes to the learning outcomes and quality of the learning process. Thus, both students and teachers need to learn when and how to use digital technologies meaning fully in the learning process and, even more importantly, when not to use them. The latter is in line with the authors' framework for digital competence, which defines at the level of transformative competence the need to consider other societal goals, such as those related to sustainable development. Every search on the Internet or, even more so, every discussion with AI and creating and training the algorithms for AI requires energy. The amount of energy needed to generate or store one bit of information is not remarkable. However, considering the amount of data recorded in AI systems or video-based technologies, it is clear that we will soon reach the Earth's limits – the matter and energy is limited, and we should not waste it on meaningless activities with digital technologies (Vopson, 2021). However, these discussions have not been explicit in studies capturing Estonian teachers' decision-making processes regarding use of digital learning.

Thus, transformative digital competence seems to be a challenge in Estonia. However, even contextual or generic competence might be challenging sometimes. The DigiEfekt study presents some evidence that contributes to the critical review of the concept of digital natives (Bennet et al., 2008). That is, the new generation of students does not appear to enter the education system with better preparation and high quality technical skills. The DigiEfekt project revealed that students' skills of performing operations required in the digital learning process were rather limited, and their behavior in the digital world often failed to follow the defined rules and restrictions. Thus, it seems that teachers need to be the change agents who guide students towards the meaningful use of digital technologies in the learning process; or, they need to design this meaningful process in collaboration with the students. Otherwise, digital learning might be seen as an academic form of "moral panic," as Bennet et al. (2008) put it when describing the debate around the concept of digital natives. What Bennet and colleagues meant is that the use of sensationalist language that dramatizes differences between generations ends up creating a form of public discourse which does not fairly represent what is happening on the ground. This again highlights the importance of transformative digital competence, which is supposed to guide the moral and ethical use of digital technologies in a sustainable and meaningful way based on a critical analysis and redefinition of the learning goals and activities.

Finally, teachers as change agents in the education system also need to be supported in developing their professional vision of digital teaching and learning. Education strategies, the national curriculum and teacher professional standards provide teachers with general guidelines for applying digital technologies meaningfully. However, these documents do not present details that are needed to change teachers' mindset towards innovative modification and redefinition of the learning activities or defining new goals and replacing some others that were important in the past, but are no longer so. For example, the national curriculum does not specifically focus on digital learning. It only mentions digital competence as a general competence, but this is not operationalized through subject-specific curricula that are guiding teachers' everyday practices. Similarly, teacher professional standards indicate the importance of applying digital technologies and teachers' responsibility for evaluating their own digital competence, but without any details on how to implement the curriculum or digital competence frameworks. Therefore, other measures of change management are necessary. Shulman and Shulman (2004) showed in their framework how teachers' learning is initiated in the interaction of individual and community level variables. In short, according to this framework, teachers learn in communities of practice where they build a shared vision or ideology and develop the knowledge base, but also share commitment and provide support to each other in the community. Thus, digital learning in school could be improved by empowering communities of teachers – or, in broad terms, educators – who can take the lead in transformative innovation towards more meaningful and effective digital learning.

With communities of educators in mind, the Educational Technology master's program was designed at the University of Tartu. The curriculum was developed in line with the principles of entangled pedagogy (Fawns, 2022) by contextualizing digital technologies and the transformation of the teaching and learning practice through digital technologies. It could be expected that a transformation towards more meaningful digital learning is achieved in this shared learning practice, where educators learn from each other by critical reflection and synthesis of their existing practices and theoretical principles of learning sciences. The results presented above show how the learning community has been one of the main benefits of the Educational Technology master's program according to the feedback of the students. What is more, it has had a long-term effect on their mindset and activities they are involved in after graduation. Thus, a similar learning communities oriented approach should be more widely applied in teachers' professional development.

In conclusion, the discussion shows that most of the schools and teachers in Estonia are in the stage of Digitalization according to the framework for digital transformation introduced by Luo and Wee (2021). It means that teachers understand what the affordances of digital technologies are, and optimize their traditional teaching and learning activities by integrating digital technologies; however, there are still several steps to take until the majority of teachers or even teacher communities in schools reach the stage of Digital Transformation. According to the students' and teachers' attitudes, the digital learning process is not meaningful, innovative and student-centered enough to allow the affordances of technologies to have a significant impact on learning outcomes. Furthermore, for some teachers and schools, we might even say that they are still at the stage of Digitization, where methods used in the non-digital learning process are merely slightly enriched with digital technologies.

Thus, the major trends in the context of digital learning in Estonia seem to be the following:

- Digital technologies are actively used in most classes, even if the purposes and ways of their usage are somewhat limited.
- Digital learning is mainly characterized by constructive assignments where students need to integrate their pre-knowledge with new content without any interaction with other learners.
- The digital competence of learners and educators is highlighted as an important general competence in strategic documents.

- There are no major restrictions or impediments that would hinder digital learning in schools: the infrastructure and rules support active integration of digital technologies. Both at school and at home, restrictions are mainly related to the general use of digital devices, but not to their use for learning.
- Teachers' professional development is increasingly organized as an activity of professional communities.

However, these trends are related to several challenges that could be formulated as major issues:

- Schools and teacher communities often lack a clear vision of the meaningful use of digital technologies.
- Teacher shortage is placing higher demands on teachers in terms of coping with the challenges of personalizing learning for students with different needs.
- Strategic documents do not guide teachers towards more specific professional development to improve their contextual and transformative digital competence.
- Students need more guidance towards effective use of digital technologies for learning, including guidance in performing simple operations required in digital learning.
- More research is needed to support digital transformation.

Conclusion

Estonia is a country branded as a "digital education nation." In international comparisons, Estonia is shown to have quite good digital readiness, and the students do remarkably well in achievement tests. Estonian teachers use digital technology actively in the teaching and learning process, and they very often provide students with assignments where they construct new knowledge by synthesizing their pre-knowledge and new material. However, there are also several challenges. For example, the digital learning process could be even more meaningful, supporting collaboration, interaction and better achievement of learning outcomes. In the future, teachers also need to be guided more towards digital transformation; this could be done by empowering teachers' learning communities. A new challenge for the Estonian education system is to critically consider AI use in education – to find a so-called sweet spot where the benefits of digital learning supported by evidence outweigh the cost to the environment. We need to find how meaningful technology use in the learning process could also be sustainable and motivating for both students and teachers, and contribute to solving global challenges, such as sustainable development and the well-being of all people. These challenges should be faced in the collaboration of teachers, teacher educators, researchers, educational technology companies and policy-makers.

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Trends and Issues of Digital Learning in Finland

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Abstract

This chapter presents trends and issues of digital learning (DL) in Finland, particularly those focusing on K–12 education. Finland has been globally recognized for its education system that emphasizes equity, high-quality teaching, and a holistic approach to learning. In general, education is highly valued in Finland and is considered a cornerstone of personal development and vital for overall societal well-being. During the past 20 years, Finland has been investing strongly in the digital infrastructure of society. The Finnish digital infrastructure is among one of the most developed internationally, and provides great opportunities for digital learning and skill development of teachers and students. However, the latest studies have indicated that digital transformation is not occurring in Finland on a large scale yet, as digital technologies are seldom used in K–12 schools for ways that activate thinking and are inquiry-based and collaborative. Finnish students also seem to adopt most of their digital competencies outside of school, which increases inequality due to students' socioeconomic backgrounds, and creates risks for unregulated overdose of the use of digital technologies in their free time. However, recent research has demonstrated positive indications as well, such as more systematic strategic planning and increasing commitment of school communities to digital transformation. A need exists for the training of preservice teachers and the professional development of in-service teachers to ensure that teachers are able to integrate digital technology effectively and in pedagogically meaningful ways into their teaching, and students are able to use digital tools confidently and responsibly for learning.

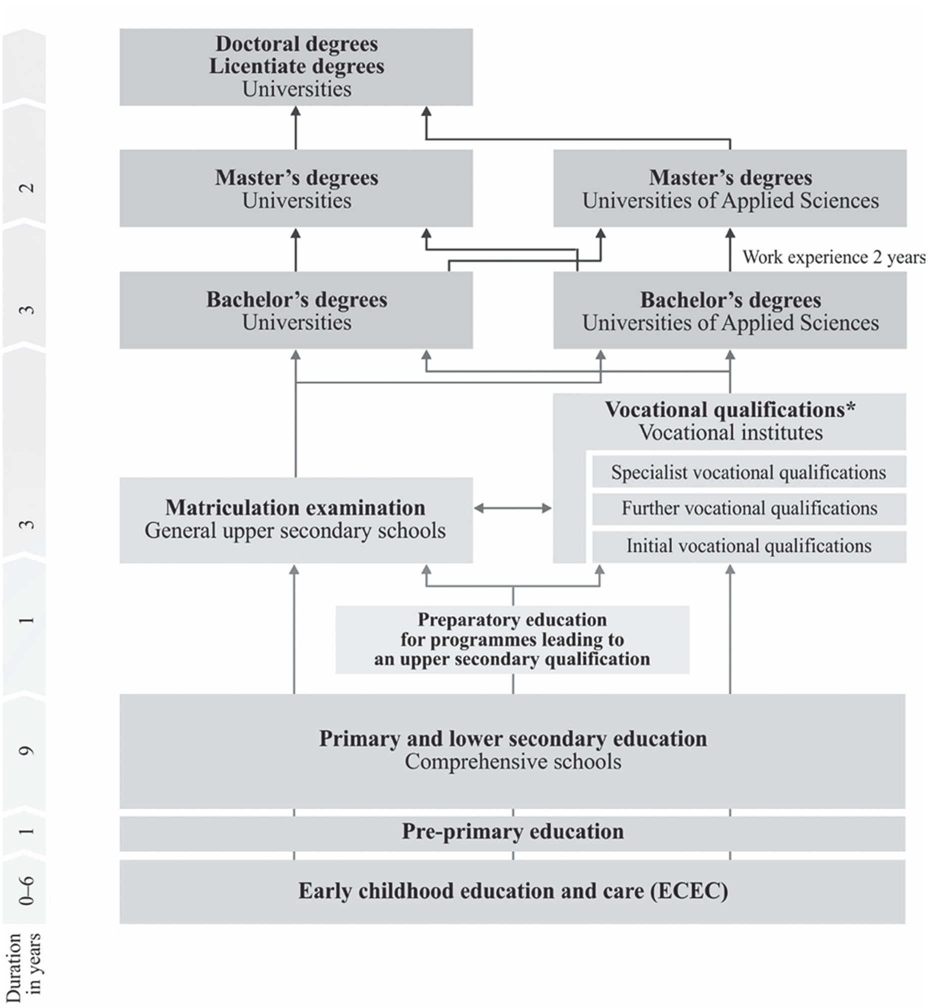
Keywords: digital learning, digital transformation, K–12 education

Introduction

Structure of the schooling system

This chapter presents current trends and issues of digital learning (DL) in Finland by particularly focusing on K–12 education. Education is highly valued in Finland and is considered a crucial aspect in a small country for supporting personal development and overall societal well-being. Finland has been globally recognized for its education system that emphasizes equity, high-quality teaching, and a holistic approach to learning. The Finnish education system is described in Figure 1. It consists of early childhood education and care (ECEC), preprimary education, primary and lower secondary education (K–12), general upper secondary education, vocational education, higher education in university and universities of applied sciences (bachelor's and master's degrees), and adult education. Compulsory education applies for all those who are 6–18 years old. It includes preprimary, basic, and upper secondary education. After nine years of basic education, general upper secondary or vocational upper secondary education and training are offered. In general, upper secondary education leads to the matriculation examination, and vocational education leads to vocational qualification.

Figure 1 Education System in Finland



* Also available as apprenticeship training or by training agreement.

Note. Modified from the materials of the Ministry of Education and Culture.

Digital transformation (DX) and the current stage in K–12 schools

Highly digitalized societies worldwide are witnessing a digital revolution that requires the renewal of human competences in all aspects of life—including educational and working environments (Haddington et al., 2021). The digital revolution, with the renewal of human competencies, may create a digital transformation of societies, including educational systems. Digital transformation of the societies has been acknowledged as a global megatrend and emphasized by several organizations, including the OECD (OECD, 2016), the United Nations in their Sustainable Development Goals (UN, 2020), and also by The Finnish Innovation Fund (Sitra, 2020). The topic of digital transformation has been gaining importance in Finland, and, in recent years, Finland has been investing strongly in digital infrastructure for education, including high-speed internet connectivity, cloud computing, and online learning platforms (Leino et al., 2023). These investments have enabled K–12 schools to adopt digital learning tools and platforms more easily, and helped to ensure access to high-quality education to students, regardless of their location, even in the rural areas of northern and eastern Finland (Tanhua-Piiroinen et al., 2020).

Finland can be considered to be at an advanced stage of digitization, digitalization, and digital transformation. Digitization refers to the process of converting analog information into digital format. In the educational context, this involves converting traditional learning materials, resources, and administrative processes into digital formats. Finland has made significant advances in digitizing educational content, including textbooks, educational materials, and administrative records. Digitalization goes beyond converting analog information to digital. It involves the integration and utilization of digital technologies to improve processes and services. In the realm of education, digitalization includes the use of technology applications, digital tools, and online resources to support teaching, learning, and administrative functions. Finland has embraced digitalization in its education system by incorporating technology applications, interactive learning tools, and digital platforms into classrooms and administrative tasks. Finland has a long history of using technology in education, and digital learning is a natural extension of this tradition. According to Kaarakainen and Kaarakainen (2018), the history of digitalization in Finnish K–12 schools includes three phases. The first phase occurred during 1998–2004, when the focus of digital development was on creating a well-functioning digital infrastructure, including the creation of internet connectivity and digital learning materials. The second phase occurred during 2005–2010, and it concentrated on evaluating the benefits of using technology for teaching and learning. During this and the previous phases, different ICT-related development and research projects aimed to explore ways of implementing digital technologies in teaching and learning. The third phase occurred during 2010–2018, and it recognized diverse needs and uses of digital technologies for learning. Since 2018, opportunities for digital learning in Finnish K–12 schools have been extended, and teachers' digital-pedagogical skills have been supported, for example, by project funding and initiatives from the Finnish National Agency for Education and the Ministry of Education and Culture. As happened in many countries worldwide, the COVID-19 pandemic accelerated the need for functional digital systems, and necessitated a focus on the topics of students' and teachers' well-being in studying and working in remote and online digital systems.

Digital transformation is a broader concept that encompasses a fundamental shift in the way organizations and institutions operate due to the adoption of digital technologies. It involves rethinking and reshaping workflows, strategies, and organizational culture to leverage the full potential of digital advancements. In the context of education, digital transformation would involve not only the use of technology in classrooms but also a reimagining of pedagogy, assessment methods, and the overall learning experience. While Finland has been progressive in digitization and digitalization, the extent of its digital transformation in education varies across schools and regions.

The Status of Digital Learning

Contexts of digital learning (DL)

Finland is among the most highly digitalized countries, and many of its services are digitalized; thus, the need to provide access to digital services for all citizens is very accurate. Some of the Finnish schools are quite innovative in providing the needed digital skills for their students; however, the current overall state of digital learning in K–12 schools in Finland indicates that some areas need improvement. When, for example, comparing the amount and quality of the use of digital learning to other high infrastructure countries, Finnish schools and teachers generally use digital learning opportunities less than those in many other countries, for example, in EU countries (European Commission, 2019; Fraillon et al., 2020; Smahel et al., 2020). Kaarakainen and Saikkonen (2021) showed that before the COVID-19 pandemic, Finnish teachers used digital devices once a week on average in different ways for different subjects. Kaarakainen and Saikkonen (2021) also pointed out that the most common use of digital technologies was related to information searching and information processing tools, such as word processing. This indicated that the use of digital technologies for activating thinking and engaging learners in inquiry- and problem-based and collaborative learning activities was rare. Thus, opportunities for true digital transformation of Finnish educational systems have not been actualized.

The differences in teachers' use of digital technologies have been explained as being due to individual reasons (e.g., digital skills, competencies, and interests), not to school- or municipal-level factors, such as infrastructure (Kaarakainen & Saikkonen, 2021). Finnish teachers are quite autonomous, and the development of digital competences and skills has often been left up to the teacher's own interest and orientation, in which case the development seems to be slow and has created some differentiation of K–12 teachers' use of technology in teaching. For example, Tanhua-Piiroinen et al. (2020), Kaarakainen et al. (2018), and Kaarakainen and Saikkonen (2021) have shown that male teachers use digital technology more often than female teachers in their teaching, and young teachers use digital technologies in teaching more often than their older colleagues. In addition, the International Computer and Information Literacy Study (ICILS), which is a comparative study of OECD countries, found that male teachers' beliefs in their digital ability were stronger than those of female teachers (Fraillon et al., 2019; Gebhardt et al., 2019). In terms of age, teachers under the age of 40 have been found to believe in their own digital skills more than older teachers (Fraillon et al., 2019; Leino et al., 2019).

While digital technologies have the potential to provide access to high-quality education, concerns about equity have been raised. Due to the differentiation in teachers' use of digital technologies, concerns about some students being left behind regarding their digital skills and competence development remain. The Finnish school system has traditionally been seen as a place to provide equal opportunities for all. As digital teaching is differentiated, there is a risk that, for example, students from disadvantaged backgrounds may not have access to the technology and digital infrastructure needed to participate fully in digital learning as well as other leisure-time digital activities that are vital for adolescents' digital culture. Finland has been working to address this issue by providing funding for digital infrastructure in K–12 schools and devices and connectivity to students who need them. The number of devices, software, and internet connectivity is no longer a high barrier to digital learning in Finland.

K–12 students' digital competences have also been explored, and studies show that development expected during the last few years has not occurred (Kaarakainen et al., 2017; Tanhua-Piiroinen et al., 2019). Although Finnish students use digital devices (e.g., computers and smartphones) actively in their free time, students report that they are learning necessary digital skills outside of school (Hotulainen & Oinas, 2022). Differences in students' digital competences are mostly explained by hobbies or free time use (Koivuhovi et al., 2022). Mere use of smartphones or computers does not explain and enhance digital literacy or competence; that is, it does not enhance one's understanding of the purpose of digital technologies. Slight gender differences have been observed in digital competences, where girls outperformed boys in some recent studies in computational thinking (Leino et al., 2019) and also performed better in digital communication-related tasks, whereas earlier studies indicated that boys performed better in computational thinking and technical tasks (Kaarakainen et al., 2017). Teachers' digital competence has slightly improved in recent years (Tanhua-Piiroinen et al., 2019). However, in Finnish schools, ICT is mostly used by teachers for their own purposes, for example, to communicate with children's guardians instead of using it for learning purposes and activating their students' thinking (Leino et al., 2019; Taajamo & Puhakka, 2019).

In summary, digital learning is a growing trend in Finland, which is driven by a desire to provide high-quality education that is accessible to all students and is versatile in pedagogy, particularly enhancing the active role of learners as well as digital skills and competence development. Two polarized extremes can be identified in the societal debate: on the one hand, the importance of digital skills and capabilities is emphasized, while on the other hand, concerns exist about the digital skills of teachers to implement digital learning in their classrooms in pedagogically sound ways to activate thinking and support inquiry-based, problem-oriented, and collaborative learning. While challenges to be addressed—including concerns about equity, the use of digital technologies, and the need for teacher training—exist, digital learning is seen as an important tool for developing educational opportunities in Finland.

DL policies, projects/programs, strategies and R&D

The first initiatives in using digital technology in education were already implemented in the 1980s (Saarikoski, 2006), indicating that the general interest in policy and practice on the topic is not new in Finland (Olofsson et al., 2021). In the 2000s, the first international evaluations of using digital technology were favorable in terms of Finnish educational policy (OECD, 2004), but the later evaluations were less positive (OECD, 2015). Since the 2010s, the educational policy around digital learning started to be more active (Olofsson et al., 2021). However, it started with the digitalization of matriculation exams at general upper secondary schools instead of developing digital learning opportunities in K–12 education. Most of the surveys on digital learning in the context of Finnish K–12 education have been conducted at the lower secondary level of comprehensive school, and much less at the level of primary schools. However, many of the R&D initiatives that have been taken support primary-level education. For example, the Innokas Network (https://www.innokas.fi/en/) encourages schools to arrange their own development activities that support the learning of so-called 21st-century skills (Korhonen et al., 2022).

According to Olofsson et al. (2021), digital competence is not directly mentioned in Finnish policy strategies. However, ICT skills and competences are referred to in the Finnish national K–12 curriculum (Finnish National Agency for Education, 2014) that was adopted in 2016. It highlights ICT skills and competences as a part of transversal competences. ICT competence in the Finnish K–12 curriculum refers to following four digital learning areas: (1) understanding the use and principles of ICT for making products; (2) using ICT in responsible, safe, and ergonomic ways; (3) using ICT for information searching, inquiry, and creativity; and (4) using ICT in interaction and networking. The flagship projects funded by the Ministry of Education and Culture can be named as an example of projects that have focused on the development of teacher education, including teachers' ICT skills and competencies to support and enhance digital learning opportunities in schools and teacher education (Lavonen et al., 2020; Lavonen et al., 2021). Another example is the New Literacy Skills (https://uudetlukutaidot.fi)—a development program that emphasizes the learner's right to digital competence and digital literacy. Among other things, the program highlights self-expression and participation, active and responsible agency, and the development of versatile critical thinking skills—all of which are highly needed in an increasingly digitalized society.

Finnish teachers and schools have great autonomy to conduct teaching by following the guidelines of the national curriculum. Therefore, the use of digital technologies varies greatly in Finnish schools and among Finnish teachers (Ahtiainen et al., 2021; Leino et al., 2021; Vainikainen et al., 2022). In addition, the assessment of the implementation of digital technologies to support students' digital skill development has proven to be challenging (Ouakrim-Soivio, 2022). For example, computational thinking and programming are a part of the ICT skills mentioned in the curriculum; however, teachers are often unsure about when and how much computational thinking and programming should be taught to their students in K–12 classrooms (Fagerlund et al., 2022). Many researchers have highlighted that computational thinking needs to be learned to understand programming to ensure that it is creatively applied in solving problems in different fields and everyday life situations (Michaelson, 2015). Computational thinking has been highlighted as an essential basic skill, along with writing, reading, and arithmetic skills. Despite its high relevance, the current practices are just being formulated in basic education and teacher education pointing to how to implement computational thinking and programming in teaching, and the skills and competencies required to be enhanced during different schooling years.

DL implementation in K–12 schools

Finnish K-12 schools have been implementing various technology applications to enhance learning and teaching. The frequency of technology applications usage in Finnish K-12 classrooms varies depending on factors such as teacher preferences, available resources, and the age group of students. While technology is integrated into classrooms, it is not used excessively or as a substitute for traditional teaching methods. The technology landscape is constantly evolving, but some of the common technology applications used in Finnish K-12 schools include, for example, the following.

Learning Management Systems (LMS): LMS platforms are used regularly to manage homework, assignments, and assessments. They also facilitate communication between teachers, students, and parents, as well as track student progress. **Educational Apps and Software**: The usage of educational apps and software varies depending on the subject and the teacher's approach. Some teachers integrate educational apps into their lessons regularly, while others use them more sparingly or for specific learning objectives. These applications could include language learning apps, math practice programs, science simulations, etc. **Digital Content and E-books**: While digital content and e-books are available in some schools, they are not the exclusive means of learning. Print materials still play a significant role in many classrooms. Schools may adopt digital textbooks and other educational materials to provide students with more interactive and engaging learning resources. **Interactive Whiteboards and Projectors**: Interactive whiteboards and projectors are used in classrooms for presentations and interactive activities, but they are not the primary method of instruction in all cases. Interactive whiteboards and projectors can be used to make lessons more interactive and visually engaging. They allow teachers to display multimedia content and collaborate with students in real time. **Online Collaboration Tools**: Finnish K-12 schools may use online collaboration platforms to facilitate group work, discussions, and project-based learning, enabling students to work together both in and outside the classroom. Online collaboration tools are used as needed for group projects and discussions, but not necessarily in every class session. **Coding and Programming Tools**: Some schools have been introducing coding and programming tools to foster digital literacy and computational thinking among students. Coding and programming tools have been typically introduced in later grades, and their usage might be more frequent in specialized technology or computer science classes. **Virtual Reality (VR) and Augmented Reality (AR)**: VR and AR technologies have been less commonly used. They might be implemented as part of specific educational projects or initiatives. VR and AR technologies can be used to create immersive learning experiences, allowing students to explore historical sites, scientific concepts, and more. **Online Assessment Tools**: Digital assessment tools can streamline the evaluation process and provide teachers with insights into student performance. Online assessment tools have been used for certain assessments, but traditional assessment methods (e.g., written exams) are still prevalent. **Video Conferencing Tools**: Video conferencing tools have gained more prominence during exceptional circumstances, such as the COVID-19 pandemic, when remote teaching and learning were necessary.

The specific applications used can vary between schools and regions based on teachers' individual preferences, resources, and educational philosophies. As such, digital technology usage is not standardized and can vary significantly from one classroom to another. The frequency of technology use in Finnish classrooms might continue to evolve over time based on changes in technology trends and educational philosophies.

The impact of COVID-19 on DL

The COVID-19 pandemic and subsequent emergency remote teaching can be viewed as a moment of global testing in terms of the digital readiness of schools. The pandemic quickly and extensively changed the digital competence needs of both teachers and learners, and highlighted society's level of digital readiness. The previously described national actions promoting the digitization of education contributed to preparing the education system and its actors—teachers, pupils, and students—in different education sectors to face the changing state of digital learning in the form of large-scale online education. This fundamental and sudden transition brought valuable information about the well-being and coping of different actors, such as principals (Ahtiainen et al., 2022), teachers (Dindar et al., 2021; Niemi & Kousa, 2020), and students (Orbach et al., 2023) and their guardians (Sorkkila et al., 2023), the challenges they experienced and their readiness for change. Now we know that some individuals were more ready for change than others: the period brought to the forefront the inequality of digital skills and opportunities between individuals, schools, and regions (Lavonen & Salmela-Aro, 2022) and a learning gap that followed the pandemic period (Donnelly & Patrinos, 2022; Engzell et al., 2021; Lerkkanen et al., 2023).

The teaching methods that were used during the pandemic were also explored. K–12 students reported that the number of tasks was greater than before, the support provided by the teacher was less available, and the online learning environments were difficult to use (Ahtiainen et al., 2021; Kankaanranta & Kantola, 2020). In schools, the situation of distance education was complicated by, among other things, their different starting points and differences in the digital skills of teachers and students. Some schools and educational institutions had an established digital teaching culture in which various learning platforms and digital applications had already been used extensively, and both students and teachers had good digital skills and capabilities, and they were comfortable engaging in digital activities. Instead, some of the educational institutions were in a situation in which distance education needs surprised all actors. COVID-19 remote education also emphasized students' individuality in learning skills, such as self-direction and self-regulation of learning. Along with the needs and opportunities for social interaction, students' lack of self-regulated learning skills turned out to be key challenges during the pandemic, putting students in different situations in terms of distance learning capabilities and realized distance education (Hadwin et al., 2022; Näykki et al., 2023). The pandemic has shown that when the means of teaching needs quick modification, the importance of different individual skills is emphasized. Thus, the potential unequal development of digital competence and digital crisis preparedness poses challenges to the equality of learners.

A somewhat surprising result is that the COVID-19 period reduced the number of teachers participating in continuing education (Leino et al., 2023). During the COVID-19 pandemic, teachers were offered continuing education and professional development courses, and the courses switched to web-mediated for some time. Web-mediated courses can promote accessibility and make it easier for teachers to schedule their personal timetables; however, they may also decrease teachers' interest and commitment to participate. According to the study by Leino et al. (2023), the decrease in teachers' participation was the highest for the courses that taught about certain applications and programs (e.g., word processing or spreadsheet programs). The least amount of participation was in courses that dealt with the educational use of ICT for students who needed special or individual support. This content is perhaps thought of as the activities of a special education teacher, even though every teacher should be able to provide general-level support to their students, if needed, regardless of whether they are engaged in on-site or distance education. When exploring the most popular ways to develop digital skills, Leino et al. (2023) highlighted the informal peer support organized in teachers' own schools. This has been found to be an important forum for sharing ideas and providing collegial support during various challenges. Of the more formal continuing education forms, participation in online discussion groups examining teaching and learning increased the most. Participation in such online discussions increased the most in northern Finland, which was statistically significantly different from other regions (Leino et al., 2023).

Digital learning infrastructure

To develop digital learning opportunities and competences, the digital learning infrastructure needs to be well developed and functional. In this chapter, DL infrastructure is not only defined as a general technological infrastructure but also includes other variables, such as leadership and budget, course design and delivery, student success for digital learning and needs for teachers' professional development.

DL infrastructure in K–12 schools

The digital learning infrastructure of Finnish K–12 schools has been continuously developed. In general, schools have enough digital devices suitable for multiple uses, and the number of devices has been increasing systematically (Tanhua-Piiroinen et al., 2020). In addition, high-speed connectivity is no longer an often-experienced challenge. These issues will be explained in more detail in the next section.

Despite technical advancements, the use of digital infrastructure in Finland has been modest, for example, in international comparison studies (et al., Leino et al., 2019) the use of digital infrastructure has been highlighted in limited ways, without any encouragement for students' active agency and as a support for thinking-activating and problem-solving tasks (European Commission, 2013; Fraillon et al., 2020; Smahel et al., 2020; Tanhua-Piiroinen et al., 2020). According to Tanhua-Piiroinen et al. (2020), teachers also prefer ready-made learning materials offered by major publishers, while simultaneously criticizing their lack of interactivity and expensive prices. The use of digital learning materials and platforms, mobile applications, digital assessment tools, and networking services has slightly increased during the last few years.

Digital learning infrastructure, in terms of leadership and budget, is an important but challenging question that needs to be thoroughly answered. In the Finnish education system, schools and their leaders are highly autonomous. This means that no central information has been collected about the ways of leading the schools' digital transformation or the budget to be used for the development of digital learning infrastructure and updating devices and program licenses. However, some positive indications for change during 2017 and 2019 have been observed. According to Tanhua-Piiroinen et al. (2020), school principals reported learning more systematically than the earlier municipal-level strategy in planning digital transformation. In addition, the importance of the whole school community and changes in operational school culture have been emphasized. During 2017 and 2019, the commitment of the working community toward digital transformation developed positively. In the process of change, principals perceive their role as enablers; they are responsible for resource allocation and encouragement for change. Digital technologies not only transform a learning organization but also offer high potential for schools. We argue that leading digital transformation in a learning organization requires different leadership approaches and organizational structures to allow more autonomous, team-based efforts for digital innovation across education ecosystems (Kowch, 2018). A new type of thinking is needed to truly adopt new kinds of processes. Innovation in education systems means much more than invention or technology adoption alone.

Key statistics and practical examples

Tanhua-Piiroinen et al. (2020) explored Finnish K–12 schools' current digital learning infrastructure. Their study indicated that almost all Finnish K–12 schools have well-functioning wireless network connections. In terms of teachers' digital devices, Tanhua-Piiroinen et al. (2020) showed that almost 57% of the teachers had a laptop for their personal use, and slightly more than one-half (53%) had received a tablet for their own use. In contrast, 13% of schools' teachers did not have any personal devices. Based on the school principals' answers, the number of tablet devices in proportion to the number of students was 0:25 on average, which meant that one device was available per four students (1:4). Of the schools, 16% had an equipment ratio of one device per two students. In only 2% of the schools did each student have his or her own device (1:1). When the number of laptop computers was compared to the proportion of students, the availability of one laptop per seven students (1:7) was evident. Of the schools, 3% had one laptop per two students (1:2). The number of desktop computers in proportion to the number of students was on average 0.08, or 1:12.5. During school visits, only one school had a separate computer classroom left, which was no longer used much. A tablet, either alone or with a computer, seems to be the most commonly available and used device, at least in the lower-grade levels of primary school.

Large school-specific and teacher-specific differences were noted in the use of students' own smart devices during school days. In some schools, students' own devices were a self-evident part of lessons, especially in tasks related to information retrieval, and efforts were made to promote the use of students' own devices, for example, by joint Kahoot! quizzes and involving students in the content production of the school's social media channels. In some schools, the use of one's own devices was completely prohibited during the school day. In one of the teachers' interviews, it became apparent that teachers could also have different interpretations of such a rule on students' access to mobile devices. That is, teachers can sometimes decide to use their own devices in their own lessons, even though their use is otherwise prohibited during the school day. This is an example of the teacher's autonomy, which can be seen here as well.

According to the 2018 ICILS survey (Leino et al., 2019), more than 90% of Finnish lower secondary schools had internet connections, wireless LANs, and central platforms (e.g., Pedanet, Wilma, or similar) and applications (e.g., word processing and spreadsheet programs). Devices and programs, which were fewer, were just becoming common or used in a specific subject (such as data collection and tracking devices and programs). Of the different types of software, the number of multiuser games with graphics and exploratory learning tasks that became available to teachers and students had increased the most. They were now in more than 60% of schools. However, the possibility for teachers and students to use the drawing and graphics programs offered by the school had weakened statistically significantly, although they were still available in 86% of the schools. Of the various devices, 3D printers and programmable robots increased significantly. In 2018, robots were found in almost two out of three schools, and in 2020, robots were already found in three out of four schools. In 2018, 3D printers were in every third school; however, in 2020, 3D printers were in every second school.

In 2018, the least equipped school had 25 students per computer, while the average for all schools was 3.2 students per computer. At the end of 2020, the least equipped school had eight students per computer, and the average of all schools had 2.4 students per computer. In 2020, approximately 30% of schools had acquired laptops for at least three out of four students to use at home or school. In 2018, the corresponding figure was only 11%. No statistically significant differences were observed in the number of computers used by students in schools between regions and municipalities or cities of different sizes. It is noteworthy that one-quarter of schools did not offer every teacher a laptop yet. In this regard, too, the situation improved, as in 2018, more than 40% of such schools had provided a laptop for their teachers.. The starting point for schools to actively use information and communication technology as part of teaching thus improved from the point of view of equipment availability. However, at the level of individual schools, clear differences were observed in opportunities for both students and teachers to use computers. Differences were also noted between schools, and even a single school had different solutions for the location and distribution of computers available to students at the same time. The most common computers in schools were, for example, laptops kept in carts that could be transported from one class to another (almost three out of four schools). About half of the schools had computers in computer classes. In other words, many schools had computers both in the computer classroom and in delivery carts. Only one-quarter of the schools reported that they had computers in most (over 80%) classrooms. Compared to 2018, the use of all aforementioned solutions in schools had decreased, and in more and more schools (a change from 29% to 41%), at least some of the students carried computers with them to class.

Features of digital learning

We selected the following four features of digital learning in Finland. These features were obtained from comparisons with K–12 schools in other equivalent countries and those between K–12 schools and colleges in Finland.

The first feature: According to an international comparative study by ICILS (Leino et al., 2019), one-third of Finnish youth have an excellent level of multiliteracy skills; however, about one-quarter of the students' skills are weak. Furthermore, Finnish students' computational thinking skills are among the top three examined countries, and Finnish girls have better skill levels than boys.

The second feature: The ICILS study (Leino et al., 2019) indicated some regional differences in skill levels (for the benefit of southern and western Finland), but a more in-depth evaluation showed that these differences were explained by the socioeconomic differences of the families. In other words, parents' or guardians' education and occupation, and the number of books at home had a clear effect on the students' skill levels. Young people with immigrant backgrounds had a clearly lower level of measured skills. Students who had been using computers for a longer time received better outcomes in their ICT tests than those who had less experience.

The third feature: What was particularly surprising in the ICILS study (Leino et al., 2019) was that only one-tenth of young Finnish individuals used ICT devices daily at school. Finnish youth used ICT devices as a support for learning less than the youth in other countries. The study also indicated that Finnish youth have learned their ICT skills mostly from outside school. Naturally, informal learning in terms of ICT skills is important, but the problem relies on when the use is not pedagogically planned and does not necessarily support skills for self-regulation of the way ICT is used.

The fourth feature: According to our literature review, a need for more systematic research on K–12 schools' digital learning has been felt to explore in more detail the current situation and future vision of digital learning in Finland. We argue that a need exists for a more systematic vision and a research agenda to examine the skills of younger students, especially at the primary level in K–12 schools. We should explore teachers' and students' beliefs about ICT skills, their actual skills, and how they view the meaning of ICT skills in a digitalized society. We should also aim for observational and classroom ethnographic research to examine how and for what purposes ICT is used during school days.

Trends and Issues in Digital Learning

Trends in digital learning

Trend 1: An emerging digital revolution

We are globally witnessing an emerging digital revolution that can be compared to the time of internet introduction and rapid development. During the past 20 years, digital technologies, such as the internet and smartphones, have transformed our working and studying environments and significantly provided new possibilities. The speed of change will be even greater over the next few years. The citizens of the world are already witnessing how, for example, artificial intelligence (AI), the internet of things (IoT), virtual/augmented/mixed reality (VR/AR/XR), and robotics are developing quickly and will soon become more ubiquitous and invisible parts of our everyday life. Such development brings not only advantages but also concerns. *New technologies speed up some routine processes and provide automation and support; however, at the same time, change needs control and ethical conciseness*. In Finnish K–12 education, such change is occurring, and some of the more advanced schools have already been investing in the infrastructure of modern technologies and exploring ways to use technologies, for example, those of VR/AR/XR. However, scaling up the use of emerging technologies is still in its early years.

Trend 2: The growing use of data, development of algorithms, increased computing capacity and interconnectedness

The next big wave of digitalization is already underway. Particularly because of the development of AI, technologies are not only helping people do things faster but are also profoundly changing the ways in which things are done (Sitra, 2016). As AI-powered applications become more common, they are expected to bring about significant changes in everyday life (Sitra, 2020). The growing use of data, development of algorithms, and increased computing capacity and interconnectedness are suspected to lead to increased use of voice-controlled machines, speech and facial recognition, traffic automation, conversational robots, and personalized recommendation systems (Sitra, 2020). *Consequently, a growing need to discuss the impact of technology and develop new competences to understand technology, and its ethical use (Sitra, 2020) also exists*. In Finnish K–12 schools, AI-powered applications are not yet in their peak development phase, but Finland is investing in R&D projects to search for ways of harnessing AI's opportunities for educational purposes. For example, the Strategic Research Council is funding the research project, Generation-AI, that aims to engage AI developers, schools, government, business, and NGOs to define technology in the AI era, that is, in terms of not only its mechanisms, opportunities, and dynamics but also its weaknesses, biases, and risks.

Trend 3: The importance of digital, technological, and information literacy

One fundamental and very specific working-life competence that is currently highlighted concerns literacies. The importance of digital, technological, and information literacies is only increasing. Possessing adequate and appropriate literacy skills means being able to critically review information and acknowledge that it is extensively available everywhere. Data literacy corresponds to this type of new competency, meaning that it is always more important for individuals to be able to understand how information is transmitted to data and how data are transformed, stored, and used in a variety of causes. Digital services and hardware collect and manage large amounts of personal data in our everyday lives (OECD, 2016, p. 15; Sitra, 2020). *While the data enable AI-based solutions with great positive potential, people have difficulty understanding what data are being collected and siloed. Furthermore, recent scandals about data misuse or leaks highlight issues of ethics and data management*. In Finnish educational discussions, data literacy and algorithmic awareness are still evolving topics. These have been recognized as important skills in a modern data-driven society; however, K–12 schools have not yet been able to actively take hold of them.

Trend 4: Learning analytics for collecting evidence of learning progression and for providing feedback channels for learners and teachers

Digital communication is also transforming and is expected to include more multimodal and intermedial materials that will combine seamless talk, writing, and various types of visual information. It can be expected that, all the time, more realistic digital spaces and places for interaction will become prevalent. For example, the development of mixed-reality environments, where realistic 3D images of places, objects, and people can be projected, will provide new possibilities for interactive learning and working. In addition, interaction opportunities with artificial and intelligent assistants will be dramatically improved in the coming years. Data processing opportunities, that is, the development of technologies and increasing computing capacity are expected to make advances in how, for example, learning analytics (LA) can be used in learning situations to collect evidence of learning progression and provide feedback channels for learners and teachers. *This digital trend calls for a focus on the reliability and safety of digital communication (OECD, 2016, p. 14), including ideas about the ethical use of LA in learning*. Finnish K–12 schools are currently implementing some of the LA tools in their teaching. One example is the ViLLE/Eduten platform (Laakso et al., 2018) that collects data on learning and provides teachers with immediate feedback on children's performance and progress, and provides policymakers with information at the group, area, and national levels. The platform uses AI-based methods (machine learning, data mining, neural networks) to capture variability and personalized learning in different subpopulations and to support learners (prescriptive LA, natural language-based intelligent tutoring).

Trend 5: Supporting human learners' unique skills of creative and flexible thinking

In general, digital revolution is affecting the future needs of working life. For example, the McKinsey Global Institute (2017) has identified the following four main skills: technical, cognitive, creative, and interpersonal skills that will account for half of the work activities by 2030. Thus, these skills should also be visible in the current school systems, highlighting social (negotiation and collaboration skills), technical (programming, technology design and maintenance skills), problem-solving (adaptive thinking and design mindset), and process skills (resource management and transdisciplinary skills). What is highlighted here, during the high speed of the digital revolution, is to remember that human learners have unique skills as compared to, for example, AI-based solutions. Learning scientists (for example, Järvelä et al., 2023, p. 1) have pointed out that "human learners are unique in using creative and flexible thinking, expressing and interpreting effects, as well as connecting thinking and action to long-term aims, values, and purposes." Järvelä et al. (2022) also claimed that it is important to not solely rely on technological advancements but to strengthen human capabilities and support learners to adapt to new situations and tasks; collaborate productively and proficiently; develop socioemotional skills; and have the ability to take the initiative, set goals, and monitor themselves and others in learning. It remains vital to ensure that current and future teachers have the resources and competencies to support their students' above-described skill development. *These skills and competencies will be the key to promoting the resilience and adaptability of individuals and nations (OECD, 2019), particularly during the different crises that will potentially affect the way we go on in our daily lives*.

Issues in digital learning

Issue 1: Digital technology is rarely used in K–12 schools for activating thinking or inquiry-oriented and collaborative ways

Even though the Finnish digital infrastructure is well developed and provides great opportunities for digital learning and skill development, the studies indicate that digital technology is rarely used in K–12 schools for activating thinking or inquiry-oriented and collaborative ways (Leino et al., 2019; Vainikainen et al., 2022). There have been increasing societal and educational policy-level discussions in Finland highlighting that the challenge of education should no longer be about information delivery. What should be aimed at is to create learning environments that use and combine different levels of affordances, such as social and technological affordances, to engage and inspire individuals' and groups' learning (Erstad et al., 2021). Research on technology-enhanced learning and teaching has been active in Finland (e.g., Järvelä et al., 2001; Lehtinen et al., 2001; Näykki et al., 2019, 2022). However, the implications of these and other international studies could be better used for the further development of digitalization in K–12 schools, and also scaled up among broader networks of schools. The 21st century skills, for example, those for learning to learn and collaboratively solve problems in the digital realm, and those for regulating one's own learning, have been discussed in Finland for some time; however, a challenge remains regarding how to support the development of these skills in practice as a part of everyday learning and teaching practices of digitalized classrooms. Learning scientists have emphasized that learning and working in the 21st century requires high-level learning strategies in individual and collaborative learning settings in addition to digital competences.

Issue 2: Finnish students adopt most of their ICT skills outside of school

It also seems that Finnish students adopt most of their ICT skills outside of school (Hietajärvi et al., 2020), which increases inequality due to students' socioeconomic backgrounds (Leino et al., 2019) and creates risks for an unregulated overdose of the use of digital technologies in their free time (i.e., social media and video games) (Tang et al., 2022). One line of discussion is also the worries of excessive digitalization of adolescents' informal environments with its harmful effects on well-being. Especially, in a public discussion, this was highlighted as one of the greatest concerns regarding the development of digitalization. For example, the discussion lately gained momentum and demands arose for legislation to control the use of mobile phones during school days. Naturally, the well-being of children and young people should be the country's top priority. However, problems related to their well-being may even increase if the schools and teachers within those schools do not support the pedagogically meaningful ways of implementing digital devices in learning, if the children and young people are not supported to learn ways to regulate their own use of digital devices and applications. We argue that only controlling may not be the best solution for finding long-lasting solutions.

Issue 3: A large variation has been found in teachers' skills and willingness to implement digital learning

Current studies have indicated that a large variation has been found in teachers' skills and willingness to implement digital learning in teaching in Finland (Leino et al., 2019; Tanhua-Piiroinen et al., 2020). Therefore, a need exists for training pre-service teachers and the professional development of in-service teachers to ensure that teachers can integrate digital technology effectively and in pedagogically meaningful ways into their teaching, and that students are able to use digital tools confidently and responsibly. One of the support actions is to focus on pre- and in-service teacher education in which digital materials and new learning environments can be used and facilitated through digital-pedagogical training (Näykki et al., 2019). Every Finnish teacher should be offered possibilities for digital skill development and told about good practices. They should learn from and with their colleagues and peers. It is also important to develop evidence-based ideas for digitalization in schools by encouraging and supporting researchers to explore the actual use of digital tools in teaching and learning. In general, a strong consensus has been reached that initial teacher education institutions play an important role in preparing pre-service teachers to take advantage of digital technologies in their future profession (Häkkinen et al., 2017).

Issue 4: Teachers' pedagogical autonomy should not overshadow students' rights to acquire the necessary digital skills

One issue to be concerned with is whether the focus of digitalization is only on adding new digital devices and digital learning materials to the teaching practice. This means that digital devices would be the driver of digital transformation, whereas we argue that pedagogy and the need for supporting learning and interaction should be the drivers of digital change. Teachers' pedagogical autonomy often comes up in discussions about the use of digital tools and devices (Tanhua-Piiroinen et al., 2020). It remains important that, based on their pedagogical skills, teachers should be able to assess and decide which teaching methods are best suited to the respective teaching content and goals, but the student's right to acquire the necessary digital skills during basic education should not be overshadowed by this. In terms of students' equal accumulation of digital skills, it is important that their achievement does not depend on the enthusiasm of individual teachers. In Finland, no criteria or minimum requirements have been defined for teachers' digital competence, unlike in several other European countries (see European Commission/EACEA/Eurydice 2019 p. 47). In such a scenario, the following question arises: Would there be a need for a national definition of the digital competences of teachers in Finland as well?

Issue 5: The lack of algorithmic awareness can negatively affect the possibilities for societal participation

Equal access to information has increased, which increasingly points to the importance of critical reading. Quickly and unexpectedly, for example, at the end of 2022, we were in a situation in which teachers at all school levels and worldwide had to consider their attitudes toward AI applications when the ChatGPT application based on the language model developed by the OpenAI research center became available to everyone. A widely shared point of view is that, for example, the importance of AI and machine learning should be understood as a permanent part of society, and its responsible present and future use is an essential part of study and working-life skills (Kahila et al., 2023; Vartiainen et al., 2021). Understanding how algorithms and data-based machine learning models guide our operations plays a particularly important role in the responsible use of online environments. The lack of algorithm awareness can affect the possibilities of participation and influence at the societal level and, for example, strengthen existing views by creating echo chambers or filter bubbles, where individuals unknowingly reinforce, for example, political or commercial messages (Gran et al., 2021). Better awareness of the operation of algorithms and AI creates a basis for active agency and provides tools for understanding the world around us (Gran et al., 2021; Vartiainen et al., 2021).

Issue 6: There is a clear need to guide all teachers in integrating computational thinking in their teaching

Schools play a key role in promoting algorithmic awareness and computational thinking (CT). However, the integration of CT through a problem-solving approach is still emerging in Finnish schools, and exposure to CT varies greatly both among teachers and students (Leino et al., 2019). Fagerlund et al. (2022) investigated Finnish teachers' and students' programming motivation, as well as their role in teaching and learning CT. The results indicated that Finnish teachers do not have a strong intrinsic motivation for programming, although they consider it a timely and important topic. Teachers with prior experience, such as STEAM teachers and male teachers, had higher programming motivation. Students with prior programming experience were more motivated on average. In addition to supporting the motivational aspects of teaching and learning CT, teachers' skills (Kong et al., 2020; Mäkitalo et al., 2019) and the quality of instruction and learning activities (Sun et al., 2022) need to be considered in promoting CT. There is a clear need to guide all teachers in integrating CT into teaching. Due to the autonomy of Finnish teachers, it is especially important to promote their intrinsic programming motivation (Fagerlund et al., 2022).

Conclusion

This chapter has identified and described the current trends and issues of digital learning (DL) in K–12 education in Finland. Countries across the globe are witnessing a rapid digital revolution that can be partly compared to internet development. The digital revolution is greatly due to the data processing power of AI and LA, which are currently transforming the landscape of studying and working (Cukurova et al., 2022; Järvelä et al., 2020; Marzouk et al., 2016). Technologies are developing quickly and will always be a more ubiquitous and invisible part of everyday life. At the same time, teachers and students need digital and ethical skills for implementing digital tools in teaching and learning processes. A need exists for the training of pre-service teachers and the professional development of in-service teachers to ensure that teachers can integrate digital technology effectively and in pedagogically meaningful ways into their teaching, and students are able to use digital tools confidently and responsibly for learning.

Finland has been investing strongly in digital infrastructure, and the Finnish digital infrastructure is among the most developed internationally. The latest studies indicate both negative and positive signals of digital transformation in Finnish K–12 schools. On a large scale, Finnish education and schools are not yet close to improved digital systems. This is because digital technologies are only occasionally used in K–12 schools for activating thinking and for inquiry-driven and collaborative ways. This indicates that the role of digital technologies is still seen as part of routine work, such as information searching and delivery. Learning approaches to activate thinking and those based on inquiry and collaboration have been shown to support highly important learning and group working skills (Dillenbourg, 1999; Jeong & Hmelo-Silver, 2016; Kuhn, 2015; Rochelle & Teasley, 1995). Many of the previous studies have highlighted a different set of skills, and all of these have a shared idea of broad skills that are not only vital for future working life but are also highlighted as learning and life skills (Binkley et al., 2012; Griffin et al., 2012). For example, by following the identified skills of the McKinsey Global Institute (2017), namely technical, cognitive, creative, and interpersonal skills, it can be argued that these skills should be visible and a central part of current K–12 education.

Finnish K–12 education is still in a transition phase. There is increasing interest, national investments, and lively public discussion on developing digital learning in Finland. However, technology is most usually seen as one tool, among many others. Teachers and principals usually experience digital resources in a way such as textbooks, pens, or other learning materials (Tanhua-Piiroinen et al., 2020). In other words, technology is seen as an everyday tool but not as a cognitive tool to promote thinking (Kim & Reeves, 2007; Kirschner & Erkens, 2006; Pea, 1993). One example of this is the role of computational thinking (CT) in teaching and learning, which is mostly interpreted as a programming or coding skill. According to Fagerlund et al. (2022), we should understand CT more broadly as computational problem solving or as a type of multiliteracy. In this way, students can also examine the practical, political, and ethical dimensions of the computational world around us (Høholt et al., 2021).

Learning scientists have pointed out that human learners are unique in the ways they use creative and flexible thinking, expressions, and interpretations of their own and other's affective reactions, as well as connecting thinking and action to long-term aims, values, and purposes (Järvelä et al., 2023). Thus, school systems should do better not only in harnessing these unique human learning characteristics as a service for learning and well-being, but also for future digital learning developments. It is vital to strengthen human learning capabilities (Hadwin et al., 2018; Järvelä et al., 2022) to adapt to new situations and tasks, develop socioemotional skills in encountering different kinds of challenges, and take initiatives and monitor themselves and others in learning.

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Trends and Issues of Digital Learning in Germany

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Abstract

The description of the German educational system reveals that fostering specific education in schools and other educational institutions is not easy for the national government due to the fact that education is up to the federal states of Germany. This chapter reveals that many different approaches to digital learning have been developed by the states and the schools, and introduces which changes have been made so far to achieve digital learning. A categorization of the different levels of K-12 schools according to their stage on the journey to digital transformation is provided in this chapter. The "Digital Pact" ("Digitalpakt," see below), which is Germany's most important initiative to enhance the digital competences of young people by boosting digital education with an historic funding program, is explained. It is shown how this program accelerated digitalization in German and why it came at the right time to provide an effective means of dealing with the coronavirus pandemic. On the basis of the Digital Pact, many innovative programs could be funded, and digital learning could be fostered in a sustainable way. It is claimed that school and teacher attitudes changed, and interest in digital learning increased. It is argued, however, that the digital change led to overload for teachers because concepts and technical administration is up to them, besides all of the teaching tasks. Additionally, the national government did not announce if and when the Digital Pact will be continued when it expires in 2024. Will the positive proceedings of the digital learning of recent years come to a turning point soon?

Keywords: digital learning in Germany, German education system, political influence on education, Digital Pact

Introduction

Germany consists of 16 federal states and therefore is officially called "The Federal Republic of Germany." It has about 84 million inhabitants and the population of the federal states ranges from 0.6 million (the city state of Bremen) to 18.1 million (the state of Nordrhein-Westfalen). It is most likely to be historically argued that educational sovereignty lies with the federal states themselves and not with the Republic of Germany. The states have their own governments and ministries and regulate many of their affairs autonomously, including education. There are many specific features in the 16 states. As a consequence, no standardized curricula exist in Germany. Therefore, one could claim that Germany has not one, but 16 education systems. Yet the states are not entirely free in their decisions concerning their educational affairs. They are comparable in various aspects and can be considered as one system. This is done in the following section, where differences between the 16 systems are also discussed when they become relevant.

For example, the 16 states have in common that the internationally used eight ICSD levels are divided into five educational levels. The German education system distinguishes elementary, primary, lower secondary, upper secondary, and tertiary education. There are various transition options between the levels. Overall, the system strives for a high degree of transferability. This is intended to enable every citizen to achieve the highest possible level of education in several ways and via different educational pathways without the education system itself setting limits. In addition to demographic effects, it is probably also attributable to this educational transferability that the number of college beginners rose from one third in 2000 to more than a half in 2010 (Turulski, 2023).

Every child must attend school for at least 9 years, in some states even longer. This time is sufficient to obtain a lower secondary school leaving certificate, which is the lowest education degree necessary for entering any vocational education program. Many options with pathways for general education or vocational education allow the achievement of higher educational qualifications, provided that the personal disposition is appropriate.

Any educational program offered by public schools is available for completion at no cost. In certain instances, however, it may be necessary for students to bear the expenses of educational materials. Relatively low fees may be charged at tertiary level universities and universities for applied sciences. Some trade and technical schools provide qualifications at ISCED level 6 that can be attended on a part-time basis. These programs are subject to a fee and must be paid for by the student or an employer. Students may apply for state subsidies to reduce their expenses for education.

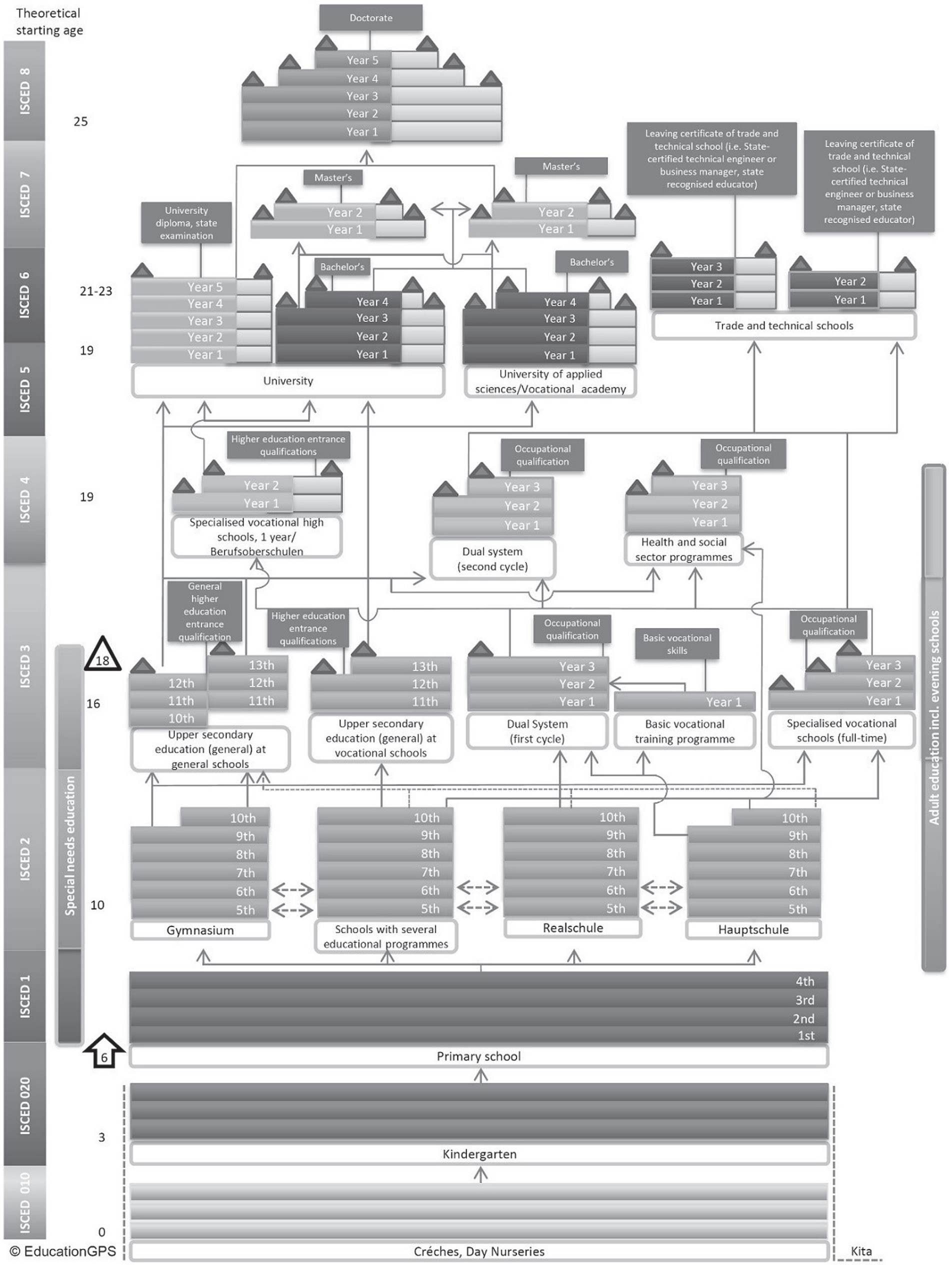
There are about 32,200 public schools of general education in Germany, which is nearly 8,000 schools less than 20 years ago. This reduction can be justified by demographic effects and by the drive to form larger schools. In 2019, 14% of general education schools were privately run, but the trend is positive, and the majority of schools in Germany are public. Private schools may receive funding from the state, but they must essentially finance themselves. They often offer a range of conditions, such as smaller courses, additional mentoring and leisure activities, or boarding school accommodation, which are not available at public schools. Nonetheless, their educational programs that lead to an official degree must be accredited by the education ministry. Private schools charge fees depending on the school's requirements so that they may only be afforded by particularly high-income parents. The attendance of private schools correlates with household income. In 2016, only 3.6% of students from low-income households attended a private school, while 18.7% of private school attendees were from millionaire income households (Grossarth-Maticek et al., 2020). As a consequence, private schools are often seen as schools for elites, even though many private schools make efforts to attract students from non-elite backgrounds, for example by awarding scholarships.

The German education system

The common structure of the German educational system is defined by national law and therefore is homogeneous across the country. The following diagram has been released by the OECD and shows

- the range of school types from elementary level (ISCED 0) to doctoral level (ISCED 8),
- the assignment of German school types to the ISCED levels, and
- the possible education pathways (OECD, 2020).

Figure 1 The German Education System



Source: OECD, 2020.

In the following section, the specific school types will be explained in more detail for each of the eight ISCED levels.

Elementary education (ISCED 0)

The elementary sector provides services for children up to 6 or 7 years of age, which is the regular age for entering primary school. Typical institutions are childcare centers like crèches and day nurseries for children up to 4 years (ISCED 010) and kindergartens for older children (ISCED 020). Assignment to programs at this ISCED level is not obligatory, but they are in high demand. Having childcare is a fundamental necessity for many parents who participate in the labor market. However, it can be very difficult to get a place for children even though many new child daycare facilities have been built in Germany in recent years. In March 2021, there were 55,000 daycare centers, which is almost 1,800 facilities more than 2 years before. Since 2006, about 9,400 new facilities have been established (Autorengruppe Bildungsberichterstattung, 2022). Elementary education institutions are seen as educational facilities and not just as care institutions. The children learn social competencies and acquire fundamental expertise by participating in learning activities such as pedagogical games, role plays, and theater, and they may attend preschool classes.

Primary education (ISCED 1)

The first obligatory school is the primary school. In most federal states, it covers Grades 1 to 4, depending on the federal state, but it may go up to Grade 6. Based on the students' accomplishments, a recommendation for secondary school is given at the end of elementary school. However, the decision is ultimately made by the parents. In the majority of its federal states, Germany regularly adopts an inclusive philosophy. Therefore, disadvantaged children are included in heterogeneous learning groups at regular schools. If this is not realistically achievable, attending a special school is an option.

Lower secondary education (ISCED 2)

After Grade 9 or 10, pupils complete educational programs that lead to the "first school-leaving certificate" (9 years) or the "intermediate school-leaving certificate" (10 years), or they prepare for a higher certification program. Qualification and school titles vary across the states. There are schools that only provide one of the two qualifications (Hauptschule and Realschule), as well as schools that offer two or three programs (with the possibility of obtaining a higher education entry qualification called "Abitur"). There are integrated comprehensive schools in some states where students can choose between multiple levels of course difficulty and get a certificate depending on the chosen classes and their accomplishments. There is a high school type called "Gymnasium" in every state where lower secondary school-leaving qualifications are obtained after 9 or 10 years as a by-product on the way to the "Abitur."

Upper secondary education (ISCED 3)

Students in upper secondary school attend full-time vocational or general education schools. The "Abitur" can be achieved after the 12th or 13th grade at a "Gymnasium" or another type of upper level general education school. Some vocational schools lead to the "Abitur" by providing upper secondary education for graduates of lower secondary schools.

Several vocational qualifications are available at the ISCED 3 level through the German Vocational Education System in three distinct sectors.

- Specialized educational schools
  Like in most European countries, this sector provides training occupations that take place exclusively at full-time Specialized Educational Schools. Programs in this sector take up to 3 years to complete and have to be legally recognized as vocational training programs by the responsible ministry. Training takes place exclusively at the school, although

practical phases in the form of company placements are also provided. The school-based training programs end with final examinations that evaluate the suitability for the future professional activity. Unlike dual vocational training, the content of these courses is regulated at the state level and is not uniform throughout Germany. With 80%, most of these programs correspond to the field of social and health service professions. STEM professions (to which professions in information and communication technologies are reckoned) have a small share, as they are preferably learned in the dual system (Schultheis et al., 2021). In this small share, the profession of "informatic assistant" is quite popular (Bundesagentur für Arbeit, 2023). However, this profession has only a proportion of 2.5% of all vocations educated in specialized educational schools.

- Dual system

  This sector is referred to as "dual" because training takes place in two educational locations: the company's workplace and a vocational school. The practical training is covered by the training company, while the theoretical elements are taught at the vocational school. The educational content is centrally regulated by the responsible national ministry. Due to that, they are standardized nationwide. The dual education takes 3 years for most professions, though for some vocations it may take 2.5 or 3.5 years. Because the trainee is working in a company, she or he receives pay. In 2019, about 47% of all people above the age of 15 in Germany had obtained their highest vocational qualification through the dual system. Summing up all students of this sector reveals that more than 50% of adults in Germany have received a vocational training degree in the dual system, and so the dual system is a very relevant education concept for Germany. The demand for education in information and communication technology in the dual system has been rising since the last decade (Bundesagentur für Arbeit, 2023).

- Basic vocational education programs

  Compared to other vocational education sectors, the sector called “the transition system” is relatively new and has been installed primarily to support young people to get into the vocational education system. In 2006, the National Education Report summarized a number of educational programs "that are below a qualified vocational training and do not lead to an official training qualification, but aim at improving the individual competences of young people to take up training or employment or also enable them to catch up on a general school leaving qualification" (Konsortium Bildungsberichterstattung, 2006). For young people and adults transitioning from school to the workforce, this sector offers training courses lasting up to a year. The goal is to increase their chances of obtaining a school- or workplace-based education choice by providing various courses to meet individual needs. Due to that, no formal education, in particular no higher school certificate, can be received in this sector. It is quite diverse, with several regional variations throughout Germany. Some of these may be accepted for the dual system's training phases, while others help young people with learning disabilities get ready for further educational programs.

In 2019, 26.3% of the entries in the vocational training system were attributed to the “transition system” sector (Maier, 2021). Before the coronavirus pandemic and up to 2021, the trend was slightly downwards (Statistisches Bundesamt, 2022). However, events of major significance (for instance economic crises) influence the demand for programs in this sector. Demographic trends and developments in immigration to Germany also have an impact on the transition system (Dohmen, 2020). Even though classes of this sector suffered in the same way like all other events that require physical presence of participants, the demand is excepted to rise due to the pandemic, for instance because of cancelled job interviews (Barlovic et al., 2020). Cancelled information events have a particularly strong impact on young people with a migration background, as they have fewer contacts with potential employers and fewer individual counseling or job application training sessions (Schwarz et al., 2020).

Post-secondary non-tertiary education (ISCED 4)

Depending on the state, programs at this level offer additional education based on an upper secondary (general or vocational) certificate, and can be obtained at a number of schools. They specialize in specific areas (such as the social or health sectors) or dual-system careers where admittance requires a diploma from an upper secondary school. Programs to get an entry qualification for higher educational programs at the tertiary level are offered by several special vocational high schools.

Short term tertiary education (ISCED 5)

At this qualification level, there are no established nationwide programs; nevertheless, some states may have unique programs for special cases.

Bachelor's or equivalent level education (ISCED 6)

At universities, colleges of applied sciences and vocational academies (trade and technical schools) in Germany, students can choose from a wide variety of study options. In 2019, more than 300,000 students received this level of graduation (Autorengruppe Bildungsberichterstattung, 2022). Even though the majority of the studies have been reformatted and internationally standardized as part of the Bologna Process, there are still some national-specific degrees, such as state examinations or diplomas, in addition to the widely recognized bachelor's degree. Vocational academies offer programs that, without attending a university or university of applied science, result in a degree equivalent to ISCED level 6 in particular professions. Many of these vocational courses are offered at evening schools on a part-time basis.

Master's or equivalent level (ISCED 7)

The Master's degree is often completed in a university and is the second degree in higher education. However, several applied science universities also provide master's degree programs.

Doctoral or equivalent level (ISCED 8)

Doctorate degrees in most cases are awarded by universities. They are considered as evidence of the ability to conduct independent scientific research. Since the Bologna Process, certain states have permitted doctorate programs at universities of applied sciences.

Digital transformation

In the following, the status of digitalization in the German K-12 schools will be described for ISCED level 0 to level 3. This will be done in accordance with a model of digitalization stages pointed out by Lou and Wee (2021). This model has been designed for companies to clarify their current status of digitalization and to provide an orientation for adjusting their business strategies for the future. It divides the status of digitalization into three stages, and digital transformation is characterized as a journey from the lowest to the highest stage. The primary goal is business success, which is expressed in successful products and a good positioning in the economic market.

Even though educational institutions are mostly driven by the state and therefore do not strive for commercial profit maximization, they must deal with numerous financial affairs to keep their educational business running. In addition, there are privately operated schools that have the pressure to generate financial income and which in this perspective are comparable to commercial companies. But in the end, education institutions are not classical commercial businesses. Even though they offer services that can be summarized as education, there is no economic market where education can be traded following the usual laws of supply and demand. The relationship of educators and students is different from the relationship between companies and customers. However, Lou and Wee's model can still be adapted to educational contexts if the economic aims of commercial companies are replaced by educational goals.

Further, education institutions can not only focus on their core aims of education such as teaching, training, educating or nurturing children and adults, they also need to administer these processes. The administration tasks are basically quite comparable to those of economic companies. Many data are to be processed. Some are shared and communicated with externals and some data are very sensitive and must not be shared with others; this concept of data security is very important. Administration processes need documentation and quality management. All in all, there is a great deal of potential for digitalization in these processes. The stage of digital transformation might be different regarding administration and education processes.

- Stage I: Digitization
  "Digitization means converting non-digital records and information into digital format" (Luo & Wee, 2021). To do this, digital devices must be available and the participants, no matter whether they are the teacher or student, must be able to operate the device. Characteristic of this stage is that activities with these devices are not connected to other activities pedagogically. In administration contexts, this stage seems to be quite insufficient. Working with digital devices like computers and digital data has been obligatory for many years. On the education side, the question of digitization is not as simple to answer because digital technologies have not been used for decades ubiquitously and in a self-evident way. Before the coronavirus pandemic, this stage was the state-of-the-art in most K-12 schools. Single digital solutions were used, for instance software for learning vocabulary, taking measurements (in sciences), generating a drawing or getting information from the world

wide web. A general strategy for digital educational aspects does not exist at this stage. Teachers and students may use digital technologies if this is an appropriate means, but there is no connecting concept to digital literacy.

- Stage II: Digitalization
  "Digitalization includes the conversion of processes or interactions into their digital equivalents" (Luo & Wee, 2021). At this stage it is necessary to connect digital solutions to gain a benefit, that is more than just the sum of the specific involved digital solutions. By integrating digital solutions into processes of education with a concept, the digital solutions support the education process in a way that is not just running a technical service. The education process will be enriched and elaborated, and enhanced learning and teaching possibilities will be enabled. For instance, learning platforms do not just provide the location-independent availability of learning material or the possibility for asynchronous communication between teachers and students. They afford new learning scenarios by supporting students with additional information and learning activities they may use whenever needed. In this way, enhanced options to supply students with individual support in the context of heterogeneous learning groups are given. To reach this stage, the education institution needs to know more than just "how to operate hardware and software products"; it needs some elaborated competences about the possibilities to conduct digital solutions, teaching and learning. Due to that, having further educated staff becomes of elementary importance.

- Stage III: Digital transformation
  "Digital transformation refers to an innovative and disruptive business transformation, where strategic decisions are made with the support of digital technologies" (Luo & Wee, 2021). This stage implies a transfor-

mation of business. For this purpose, new outcomes (products or services) must be provided. Adapting this to schools and other educational institutions raises the question of what kind of products or services they have. Basically, they offer educational programs. In Germany, these programs are predefined at an abstract level by the state of Germany and the federal state (as described above). Further on, educational facilities have to deal with the financial and infrastructural conditions set by the local authorities. As a consequence, the influence on transforming educational services is limited, but there is some freedom for schools to produce digitally transformed services and curricula. This way, digitalization can be integrated into the curriculum and can form a core learning objective in single subjects or even at the interdisciplinary level. Next to the pre-defined educational programs, there are other services like child care, extracurricular classes, workshops and other services that are extra-curricular and have the freedom to address the students' interests and demands much more directly than classical education courses. Due to the fact that schools compete with each other in the way described above, they tend to shape a school profile that appeals to students and those who have to choose between school options in the near future.

The three stages of digital transformation will be regarded separately for education and administration purposes. On the administrative side, the educational institutions are comparable. For many years digital information technologies have been used to facilitate and enhance administration like in many other business fields. Most of the educational institutions are in the public's hands. This means that superordinate authorities often specify the requirements for administration processes, and sometimes even the tools which have to be used for administration. Even though there are strict frame conditions, and the authorities in Germany do not have a reputation for being particularly innovative, the lower institutions do a professional job of administration. A large part of the data is available in digital format and is also processed digitally with the corresponding hardware and software. On the other hand, in some cases German authorities still operate in an analog way and adhere to classical, paper-based data. The reasons for this are not obvious and may be caused by the complexity of the administration process that includes many different people and authorities with different responsibilities, by reasons of data security, or simply by the aversion to change that authorities are often said to have. Anyway, digital data are omnipresent in public and privately-run education institutions. Therefore, there is no question that the prerequisite for stage I is a given.

By using networks, authorities began to connect databases for making the processing easier and faster. By sharing data via the internet, hardware and software components of different authorities can communicate nearly in real time, making the transfer of data by post unnecessary, thus greatly accelerating processing. Some services can be made use of via the internet without needing to visit the office in person. By developing the way of processing (digital) data in an efficient way, the authorities in general have become much more customer-oriented in recent years, and therefore they reached stage II of digital transformation for the most part. When considering the administration of education institutions, this is not so clear. Administration is not the core business of educational facilities where there are often just a few staff for administration tasks. In many cases pedagogical staff must perform administrative tasks on the side. When data have to be transferred to a higher authority, the tools for realizing this are predetermined and cannot be chosen by the institution. As a consequence, possibilities for innovating the administration are very limited. Instead of this, innovation is to be focused on the educational part of business. If we want to state it in a positive way, we can say that educational institutions are on their way to stage II. Some are further along than others. In summary, however, it must be stated that stage II is still far from being achieved across the entire country and to a satisfactory degree.

Stage III of digital transformation implies that there is a drive and a demand for generating new services. Public authorities do not offer their services in an open market, and clients have no choice when it comes to administration services by authorities. Due to that, clients are not customers in the classical sense. They do not demand an administrative service like they demand a product or service hosted by an economic company. Public administration is not a product, it is more like a means to a wanted end (for instance, the registration of a car). Therefore, public administration is not at stage III and it is not even heading towards it in general. The same can be said for the administrative side of educational institutions.

On the educational side, the stage of digital transformation needs to be regarded in more detail, because the educational business varies greatly regarding the specific education institutions of K-12 schooling. Because of that, the stages of the digital transformation process will be described for each ISCED level separately. It should be considered that there are many variations of digitalization in the different states and even in different institutions in the same district. The following descriptions therefore describe the state that most closely corresponds to the average at each ISCED level.

Institutions of elementary education (ISCED level 0)

In general, K-12 includes preschool education of children at the age of 5 or 6 years. At this age, children in Germany regularly pass the last year in kindergarten. Due to that, day nurseries or crèches for younger children will not be described any further in this section. K-12 education begins with kindergarten, which is part of child-care-services (Kita) before children get to primary school at the age of 6 or 7 years. In general, in kindergartens children learn by doing, often by playing and interacting with the environment and other children. Exploration is how young infants learn because they use their senses to investigate, figure out how things work, and interact hands-on with their surroundings. The last year of kindergarten is specifically to prepare the children for entering school education in primary school (preschool year). The children get in touch with new learning approaches like concentrating on given tasks, working with school typical media, listening to educators for longer amounts of time, and knowing basic cultural concepts like numbers or letters. By doing this, they may use digital devices like intelligent pens (interaction with talking pens that react to what the child is pointing at with the pen). They may even work with tablet computers and pedagogical applications in some contexts. However, there is also the viewpoint that existing concepts and offerings in daycare centers should be meaningfully enriched by digital elements (Lepold, 2022). In this way, two basic competences should be fostered:

- Gaining abilities and experiences in practical use of digital media (for instance taking photos, video clips or audio records with a tablet computer)
- Understanding medial code systems (for instance formats of files and programs, reality and fiction) (Lepold, 2022)

In 2004 the "Standing Conference of the Ministers of Education and Cultural Affairs" (Ständige Kultusministerkonferenz [KMK]) published the "Common framework of the federal states for early education in day care facilities for children." This national framework has been updated continuously and claims in the current issue that it is a central challenge to enable children to deal with media of all kind, so that they can take advantage of additional opportunities for social participation. The use of digital devices and components of information technology is given as an example of sufficient media education for early education (Kultusministerkonferenz, 2022). However, this framework is just an abstract description of what should be. In reality the available devices differ greatly between the specific kindergartens. The use of digital media in kindergarten's preschool year is more sporadic and isolated from other educational concepts. This corresponds to the finding that even at home, children between 3 and 6 years use digital media on only one day per month (Autorengruppe Bildungsberichterstattung, 2022). According to the digital transformation process, the kindergarten preschool education at ICSED level 0 accords to stage I of Lou and Wee's digital transformation concept. At the interface between educational pedagogy and administration, there is a range of digital tools that simplify the gathering and documentation of kindergarten children's competencies (Reichert-Garschhammer et al., 2021). Provided these tools become widespread and their results are fed back into pedagogical work, preschool education in kindergartens may reach stage II in the future. In some specific cases, this level may have already been achieved.

Institutions of general primary, lower and upper and secondary education (ICSED levels 1 to 3)

Even though there are different types of school for general education, they share some overall characteristics when it comes to digital transformation. As already described, the educational landscape is very heterogeneous. Depending on individual conditions at schools, they may approve digital innovation more or less fast and often. Most schools can only purchase digital equipment when external funding is provided, for instance by companies or foundations. Not every school succeeds in recruiting external funds. As a consequence, the state of digitalization differs greatly between schools. The Digital Pact may have further escalated the problem. Even though its overarching goal is to spread digitization to all schools, numerous pilot projects have emerged that directly benefit only a few schools. This means that other schools are not enhanced directly by the Digital Pact. For them, the only hope is that at least parts of the pilot projects will eventually be extended to other schools. In 2019, a teachers' union conducted a survey asking teachers and students to give their school's digital equipment a school grade. On average, only the grade "satisfactory" was given, which, according to the German school grading system, is the worst grade with which you can just barely pass an exam. In 2017, a foundation provided a survey that revealed five central findings (Schmid et al., 2017):

- Schools failed to recognize the educational potential of digitization. Only 15% of the teachers were experienced users of digital media. Not even one in four teachers believed that digital media help to improve the learning success of their students.
- There was a lack of concepts and strategies for digital education. Only 8% believed that digitalization may be of strategic relevance. The teachers decided individually if and how digital media were used in classes. They had to engage in further education on their own initiative.
- Schools suffered from insufficient infrastructure. More than half of teachers were dissatisfied with the IT infrastructure (wireless LAN, IT support, specific training).
- Video was the most popular digital learning media, followed by wikis and standard office software. Another study even pointed out that standard media like presentation software, office applications, videos and PDF-files were the most often used by teachers, even though these media were not specifically designed for pedagogical use (Anders, 2018).
- Digital learning content was particularly used if it was for free and verified. About 50% of teachers complained that searching for good content takes too much time.

The survey was released just before the government implemented the Digital Pact, and revealed the initial conditions for the pact. In addition, the COVID-19 pandemic emphasized the importance of digital education.

Primary education (ICSED level 1)

Primary schools have specific problems in gaining digital education. Since they are often smaller than secondary schools and have fewer students, they get less money from the school authorities. The Digital Pact seems to have improved the situation at primary schools at least in some cases. Zhilisbayev (2023) claimed that the equipment of elementary schools with digital (end) devices has progressed as a result of the pact. This impression was confirmed by several reports of primary schools (Norddeutscher Rundfunk, 2022; Trogisch, 2019). In contrast, Zhilisbayev pointed out that the conceptual aspect of digitality in primary schools is still underdeveloped. Studies show that the didactic use of digital devices and the question of teaching content remain largely unresolved, and the objectives are inconsistent. The intended school-based "digital basic education" and the acquisition of basic media skills are thus in danger of being missed in many cases (Schmeinck et al., 2023). Often, the IT installation, administration, and reparation are up to the teachers themselves, because no technical staff exist at many schools (Deutscher Philologenverband, 2021). The affinity of primary school teachers is often more oriented towards the pedagogical than to the scientific-technical level. Due to that, there are fewer human resources and less digital development in primary schools (Rohde & Wrase, 2022). To sum up, digitalization is heterogeneous in primary schools, but as an effect of the pandemic most of them seem to have and use the equipment and infrastructure, but it often lacks the connecting concepts, and there are still schools that have a lot of catching up to do. Due to that, on average primary schools are at stage I, “digitization.”

Lower and upper secondary education (ISCED levels 2 and 3)

There are different paths in the German education system to achieve the German equivalent of K-12 graduation, the “Abitur.” On some paths, students have to change school when progressing from lower to upper secondary level. The classic way means staying at the gymnasium for both levels. In this case, there is no difference between the levels because both take place at the same school. In general, the differences between lower and upper secondary level are not significant on average. Indeed, the variations between specific schools (even at the same level) may be much more relevant and depend on where the specific school is located and how the local authorities foster digitalization in schools (Hirsch, 2022). In addition, a study in 2021 highlighted the fact that digitization-related developments in the federal states continue to take place at different speeds and with different emphases. Thus, the educational opportunities of children and young people in the area of digital education as well as the framework conditions for teaching and learning continue to vary despite nationwide strategies (Lorenz et al., 2021). A generalized, nationwide description is also difficult for secondary schools because of the disparity between schools and states. However, studies reveal that secondary schools like gymnasium and comprehensive schools are often more digitalized than primary schools (Rohde & Wrase, 2022). As a consequence, the results of the 2018 International Computer and Information Literacy Study (ICILS) showed that, on average, eighth-graders at schools with upper secondary level were more digitally literate than those at schools with lower secondary level only (Eickelmann & Drossel, 2020). Because the students of secondary schools are older, they have more differentiated options for using digital devices as a tool for the achievement of higher-level goals. Accordingly, the device is not just a tool for learning directly supported content that must be provided by someone (like an application that helps learning how to calculate). Instead, it becomes a universal tool that can be useful for generating new content that must not be pre-generated by someone else. Older children are able to use applications that are not designed as a learning aid, but as a professional tool for multiple purposes. Due to that, it can be assumed that the connection of specific digital solutions is much easier to realize and can be integrated into pedagogical concepts that are not bound to specific content.

This effect also benefits the upper secondary vocational schools at ICSED level 3. The vocational gymnasium is open for all who graduate from lower secondary school with the completion of 10 grades. It combines general school subjects with career-oriented subjects of specific vocational fields, for instance technology or business. Despite the different subjects, it is quite similar to the upper secondary part of the general gymnasium; in particular there is no training on the job and no longer internship in companies. Specialized vocational full-time schools lead to a vocational degree that qualifies for a profession, but not for admission to a university or university of applied sciences. At the vocational schools that belong to the dual system, the content and the equipment are more focused on occupational activities. If these activities belong to the field of information technology, the school may provide more digital education than others, because the focused profession includes digitalization. In other vocational fields, the stage of digitalization is comparable to any other school at the upper secondary level.

There may be some schools that use digitalization for sharpening a school profile to be more attractive compared to others so that they would be supposed to be at stage III, "digital transformation." However, on average, lower and upper secondary schools are supposed to be at stage II, "digitalization," with upper secondary level schools appearing to be slightly more advanced.

The Status of Digital Learning

Contexts of digital learning

The national government of Germany has only a limited influence on the specific realization of the education system in the states, because many aspects of realizing education like releasing policies, allocating funds, installation of school subjects and making superordinate digital infrastructure and services available are the responsibility of the federal states and the local authorities. This even leads to different school subjects, diverse curriculums and various pedagogical approaches. For instance, there are very different approaches in lower secondary education. Some states divide the students according to their scholastic performance in three different types of school (Hauptschule, Realschule, Gymnasium) that lead to different graduations that enable students to follow different paths in upper general or vocational education programs. Other states just have gymnasium and comprehensive schools, both of which can offer paths to "Abitur" (lower degrees are awarded if the "Abitur" cannot be achieved and the school career ends after 9 or 10 years). Of course, there are different regulations for different concepts of education.

But even the states cannot directly control any specific aspect of school education. Another relevant decision-making stakeholder is the local authorities. They realize the funding of the associated education institutions and may have control over the infrastructure schools have to use. This way, they do indirectly influence the digital infrastructure by investing in or limiting funds, and they can directly influence it by binding the education institutions to specific IT solutions. Instead of this, tertiary education institutions (like universities and universities of applied sciences) are quite free to design their own digital infrastructure and curricula, because they are institutions of the state and they are financed directly by it. As such, the local authorities have much less influence.

Depending on how strict the regulations of the municipalities are, schools and other education entities can be quite free in their decisions when it comes to IT solutions in hardware and software. Therefore, schools in the same locality may use completely different IT equipment for administration and education. Each school in Germany is setting up its individual curriculum for its classes, including subjects that are relevant for digital education. Furthermore, teachers may have the option to choose between different curricular content depending on the specific conditions of courses. The provided subjects of schools form the school's profile and depend on local impacts like availability of (IT) infrastructure and teachers, local traditions, demand of students, supposed attractiveness, and the expertise and personal inclinations of the school's teaching staff. In some way, schools compete with each other because the more students they get every year, the higher the funding they receive. Providing a good digital education can become an important advantage in this competition these days. The multiple responsibilities for educational affairs at the national level, the states, the local authorities, the specific schools and the teaching staff result in a very heterogeneous educational landscape in Germany concerning infrastructure as well as curricular content. This is particularly the case when it comes to relatively new issues such as digital infrastructure and digital education concepts.

At the federal level there are just a very few aspects of general school education regulated by law (German basic law). For unifying vocational education, there is a specific national law (vocational education law). All other regulations are given to the states. An important stakeholder when it comes to educational affairs is the "Standing Conference of the Ministers of Education and Cultural Affairs" (Ständige Kultusministerkonferenz [KMK]), which specifies numerous aspects for education at the state level. These requirements relate, for example, to the basic structure of the education system or to curricular requirements at an abstract level like a framework, to which the states must adhere (Kultusministerkonferenz, 2021b). The KMK never issues specific regulations in detail. This way the states have some liberty when generating specific policies on the basis of the KMK specifications. The KMK for instance is responsible for standardization of school curriculums. There are KMK standards for most school subjects, but they are so abstract that any state can set up individual curriculums or delegate the writing of specific curriculums to the schools.

Currently and in recent years two important investment programs for digital education have been released by the national government, the "Quality Offensive Teacher Education" and the "Digital Pact."

Quality offensive teacher education

In Germany, becoming a teacher at any school from ISCED level 1 needs a master's degree that has to be achieved at a university. In 2013, long before the coronavirus pandemic and in no connection to the Digital Pact, the government set up the "Quality Offensive Teacher Education" to foster teacher education at the universities. A total of 500 million euros were provided which universities could apply for with innovative projects that should enhance for instance the structures of teacher studies, the connection to teaching practice at schools, and teacher student consulting. In 2018, an addition emerged to foster the digitalization in teacher education exclusively between 2020 and 2023 (Bundesministerium für Bildung und Forschung, 2022). Even though some projects assessed or improved specific aspects that are even connected to the efforts of the coronavirus pandemic, the “Quality Offensive Teacher Education” was inappropriate for short-term interventions to address the pandemic situation. The projects focused on universities and teacher education, so it is very difficult to evaluate the direct impact on the specific situation in schools.

The Digital Pact

To illustrate how difficult it is for the German state to gain specific changes in the approximately 32,200 schools in Germany, and how the coronavirus pandemic impacted the educational system, the emergence of the biggest digital education program in the history of Germany is described here briefly. In 2014, the German national government announced a new education offensive in its "Digital Agenda 2014-2017" (Die Bundesregierung, 2014). In October 2016, the national Ministry for Education and Research released a strategy paper called “Education offensive for the digital knowledge society” (Bundesministerium für Bildung und Forschung, 2016), whereby an investment program for the enhancement of the digital infrastructure with a simultaneous commitment of the federal states to foster the digitization of the education system was announced. Just 2 months later, the KMK released an important strategy paper for digital education. The paper, “Education in the Digital World,” describes a concept of action in which learning in the context of the increasing digitalization of society and the working sphere as well as critical reflection on this are becoming integral components of education in any education path on any ISCED level from level 1 (Kultusministerkonferenz, 2016). Hence, digital competencies are becoming an integral part of the subject curricula of all subjects. The paper defined six competence areas and set a deadline of 2026 for realization by the states. To achieve this ambitious goal, it claims five fields of action for school education (for instance further teacher education, digital learning platforms, cooperation with partners from industry and other school-externals). Then it took 2.5 years to change the German basic law, which was necessary to enable the national authorities to invest money in the educational institutions at all, which are the states' and local authorities' responsibility. In May 2019, the Digital Pact finally came into effect, and the government made 5 billion euros available, which educational institutions could apply for via school authorities and the federal states. In addition, the local authorities and the states were also allowed to apply for funding for projects. In some projects, several states could be involved. Because of the complicated and lengthy application process, initially significant funds could be paid out. Apparently, many institutions shied away from this effort, and concerns arose that the funds would not be fully accessed. It has to be mentioned that this happened prior to the pandemic conditions. There was no acute pressure on the schools to quickly become digital.

Just one year later, the coronavirus pandemic reached Germany. In March 2020, schools had to close down and were unable to teach in person as usual. From one day to the next the Digital Pact became much more relevant, especially for schools. To provide fast support for schools and to shorten the time-consuming application process, the national government made three supplements of the amount of 500 million euro each. In July 2020 the "Immediate equipment" supplement was provided to enable schools to purchase devices and software licenses and carry out distance learning services via the internet. In November 2020, a supplement for administration of equipment and services was issued, because many schools had a lack of specific competence and staff. In January 2021, another supplement was realized to enable schools and school authorities to provide their teachers with mobile digital devices like laptops, notebooks, and tablets. It is important to realize that a leading industrialized country like Germany had not equipped its teachers with mobile devices before 2021! But even after that, many teachers were forced to use their private devices for teaching because not all teachers could be equipped simultaneously, and the devices would quickly go out of date, or restrictive administration requirements would prevent flexible use. In December 2021, still with the presence of the coronavirus pandemic, the KMK published another supplementary recommendation. In its paper "Teaching and Learning in the Digital World," the KMK focused on the necessary digital school development processes and on the qualification of teachers in didactic and technical terms (Kultusministerkonferenz, 2021c). While the first paper fostered the initialization of the digital transformation by setting up the infrastructure, this paper aimed to improve the quality of education by making more use of the infrastructure in the process of teaching and learning, and to make the options of digitalization usable in pedagogical contexts. Currently all funds of the "Digital Pact" (6.5 billion euros) are scheduled and committed, and the pact ends in 2024. At the moment, there is a lot of debate about whether and when the pact will be continued. It seems that a new pact will not start before 2025, so there will probably be a funding gap. Some even fear that there will not be a continuation at all (Kuhn, 2023).

Many projects have been enabled by the Digital Pact, and some of them run at the national level and connect the states. For instance, SODIX / MUNDO aims at systematizing the many different open educational resources by analyzing via AI, setting keywords and assigning them to different curricula. It is providing an interface and exchange platform for educational media. MUNDO is an open access library that checks these media and makes them easily accessible for education. Those media that are not open will be usable with the help of VIDIS, which connects all users of any school learning platform to didactical media like learning apps or digital school books. The project TBA (Technology-Based Assessment) is in the process of developing a testing infrastructure for the development, administration, and evaluation of online-based diagnostic and performance assessment procedures.

Digital education is a cross-cutting task across all states. The KMK recommends that digital education be taught integratively, which means that all subjects must be concerned with it. However, the states are also free to set up corresponding school subjects. Some states already reacted to these recommendations and made adjustments to their curricular frameworks (Kultusministerkonferenz, 2021a). The states are realizing digital education very individually. This becomes obvious when regarding the school subject, "informatics" (internationally often referred to as computer science). In the state of "Mecklenburg-Vorpommern," "informatics" is an obligatory subject from Grades 5 to 10 (ISCED level 2) in any type of school. In contrast to this, the state of Hessen and the city state of Bremen have not implemented any informatics education in these grades so far, not even as an optional subject or as an integrated Focus in other subjects (Schwarz et al., 2022). The Association for Informatics issued an overview of digital education in the 16 federal states. Eight states have digital education as a specific subject or as a combined subject as an obligatory class in all or at least in two grades of lower secondary level. In six states there are optional classes, and two states have not yet embedded any digital education in the school subjects. At the upper secondary level, 13 states have optional and three have obligatory classes (Gesellschaft für Informatik, 2022).

Digital learning infrastructure

Current literature consistently emphasizes that the infrastructure at individual schools varies greatly and correlates to a large extent with the financial strength of the respective state and the responsible authorities. There are pilot schools that are very advanced, as well as "digital deserts" (Anders, 2018; Class, 2023; Hirsch, 2022; Kuhn, 2023; Lorenz et al., 2021; Rohde & Wrase, 2022; Schmid et al., 2017). Due to that, it is very difficult to describe the infrastructure on average. Nonetheless, the following table attempts to show this according to the six categories of digital learning infrastructure (Fox et al., 2021).

Table 1 Digital Learning Infrastructure

Leadership and budget	The leadership is up to the head of school, but it is also influenced by the local authorities and the state. The realization of digitalization is often delegated to the teachers. The authority allocates the budget, but external funding is possible.
Course design and delivery	There is no general documentation about the learning content (courses), because the schools specify individual curriculums according to the state's and the KMK's standards. The delivery is up to the school; the authority or the state may provide some infrastructure.
Student success for digital learning	The access to devices, learning materials and support varies a lot in Germany. The situation is better in gymnasiums than in other schools.
Evaluation and analytics	Some learning platforms provide evaluation services. The national project "TBA" will certainly enhance the situation across Germany.
Teacher and staff professional development	Administration staff are in high demand at schools. The further education of teachers has become a focus but is still very different between the states.
Technology infrastructure	Depending on the financial power of the state and the local authorities, it varies a lot. There are very well-equipped schools as well as schools that lack technology infrastructure. WLAN, Internet access, digital whiteboards, tablets and a learning platform are considered good infrastructure.

The coronavirus pandemic showed some trends in school education. In 2021, it prompted many teachers to become more involved with digital education and to use it more frequently. As a result, the use of digital media increased, and that had a positive effect on teachers' media-related skills. In 2017, only 15% of teachers were competent users of digital media (Schmid et al., 2017).

Teachers stated that during and even after the pandemic there was a higher motivation to use it more often. Compared to 2017, in 2021 the fostering of students' digital competencies did not vary on average, even though there are significant differences between the states. The constant level of digital competencies was confirmed by the International Computer and Information Literacy Study in 2018; German students were considered to have scientifically higher competences than the international average. However, one third had only rudimentary digital competencies (Bos et al., 2019). Unfortunately, the ICILS report 2023 is not yet available. In 2021, teachers could partially confirm that the investment programs were having an effect. The IT equipment is still in deficit; only 57% of teachers consider the equipment to be sufficient. This is true even for basic infrastructure. About 39% complained about the lack of wireless LAN connectivity in the classroom, and 46% pointed out that the internet connection in their school was not sufficient. Finally, there are noticeable differences in the training courses for teachers on digitization (Lorenz et al., 2021). In 2022, a digitization push at schools and among teachers was described by Rhode and Wrase. Nevertheless, there are still significant gaps in the basic digital infrastructure of German schools. Especially in primary and lower secondary schools, wireless LAN, learning management systems or networked collaborative tools are not available (Rohde & Wrase, 2022).

Features of digital learning

Comparing the German K-12 education with other countries or with German colleges reveals some features of digital learning in Germany. A very special feature that is characteristic of German K-12 education is the curricular freedom of any single school. The KMK as well as the states are just defining frameworks at the abstract level. Each school is free to define its own curriculum for each subject. This way, the learning content over a school year is never the same between two schools. What makes it very difficult for overall reporting is a feature in the perspective of the schools, because they have the opportunity to integrate local aspects into their curriculums. Another feature is the freedom to teach subjects with different intensity and in different grades. There are even subjects that can be taught optionally. This way, the schools can adapt their teaching program to the local conditions, for instance to the availability of teachers for digital education classes or to the demand resulting from voluntary courses. The funding of digital education in Germany can also be seen as a feature in some way. For a long time there has not been a special funding program besides some smaller programs in the states. In recent years, however, a huge amount of money has been invested in funding digitalization in schools. By setting up the Digital Pact, the digital transformation got a strong initial impulse and an enormous acceleration. The program came just in time to enable schools to react to the conditions given by the coronavirus pandemic. The three extensions restored teaching capability as quickly as possible, and the schools were able to purchase what they most needed for a fast transition to online teaching. In that sense, the pandemic and the program complemented each other perfectly and really have been a game changer. Both were very relevant for the rapid digitization progress of recent years.

Trends and Issues in Digital Learning

Trend 1: Teachers' interest in digital learning is rising

Before the coronavirus pandemic, many schools and teachers had no need to set digital education as a high priority. Developing digital learning concepts, applying for funding and supporting digital solutions were an avoidable option. During the pandemic, classical teaching was suddenly no longer possible, and there was an acute need to address digital media with high priority. The Digital Pact also provided the necessary funding, so the need and opportunity were there at the same time. As a result, there has been a rapid rise in interest in digital education. Many teachers gained (initial) experience and learned about the possibilities and limitations of digital media. In the meantime, digitization has become a matter of course, and it is hard to imagine most schools without it. Overall, interest in digital education among teachers has gone up sharply.

Trend 2: Change in school culture

Just a few years ago nearly no general school used a digital platform, and digital media were mostly used as additional presentation media. All communication between students and teachers, and between parents and teachers was paper-based. Nowadays, digital communication via a platform is state-of-the-art. It is more flexible, more reliable and much faster. Even bidirectional communication is easily possible. The use of these services essentially changed the fundamental school culture. Schools are not ponderous authorities any more but are seen as innovative institutions. This trend is now unstoppable, as a lasting commitment has been created. The projects ongoing through the Digital Pact will make new and advanced services available, so this trend is likely to continue.

Trend 3: Digitalization delivers options for diverse groups

Digital media make it possible to present different types of content in parallel and thus meet the individual needs of students. In this way, different levels of proficiency can be addressed. The use of different modal channels also makes it easier for students with special needs to learn. However, profitable use is associated with a change in school learning cultures, especially when face-to-face teaching and digitally supported learning are combined. This is one of many new fields of research in the context of digital learning.

Trend 4: Informatics as a rising school subject

The association for informatics pointed out that digital education must be viewed from a technological, socio-cultural and application-related perspective (Gesellschaft für Informatik, 2016). Due to this, informatic education is not just done by programming computers. More and more countries have started to offer informatic education by implementing the subject "informatics." In this way, digital education will be achieved in most of Germany's states.

Trend 5: Teacher education and further education is being renewed

The changed conditions in schools must also be reflected in the training and continuing education of teachers. Teachers are increasingly demanding training in digital education. The range of training courses on offer is being adapted accordingly. The federal states have realized that digital education can only work well if the teaching staff are educated in the technology and didactics of digital education. The same change of further education can be claimed for universities. The teacher education here is also updating its curriculums to integrate digital education in teacher education programs.

Issue 1: Innovation in education is very time consuming

Compared to other developments, the changes in digital technologies occur very frequently and fast. For instance, the release of ChatGPT in November 2022, that uses artificial intelligence to deliver a chatbot service, had a huge impact on economics and society. Just 2 months after its release, it has been used by more than 100 million users worldwide (Heaven, 2023). Educational innovations are time consuming because introducing a technology in an educational context is much more than just getting the technical solution running. The work on pedagogical concepts is just starting after the solution is already working. Because the schools are so different, approaches must be tested and experiences must be had. After that, the solution may have to be modified or pedagogical compromises may have to be found and accepted. This process can take years because the innovation does not take place in a laboratory under ideal conditions but in real courses and in regular classes. There is a danger that education will no longer be able to keep pace with technical development.

The many responsibilities for educational affairs in Germany delay innovations even more.

Issue 2: A lack of teachers

There is a shortage of skilled workers in many industries. This is particularly the case in IT professions, where many positions cannot be filled and orders cannot be processed. Teachers are also in demand in Germany. There is a shortage of teachers, especially in the STEM subjects, and not all positions can be staffed anymore. Not only the teaching hours, but also all the other tasks that teachers perform have to be divided among fewer staff. Since there are rarely any additional staff at schools, 92% of teachers are overworked and have even less time and energy for innovations in digital education; 79% need to work on weekends, 50% do not comply with the legally prescribed rest period, and every fifth person is even working at night very often (Sichma et al., 2022). It is obvious that the overload of teachers has negative impacts on any innovation process in school, including digital education.

Issue 3: Limitations due to data protection

Germany has strong privacy regulations. It is up to the states to ensure that in schools, privacy is ensured, too. Therefore, they released specific data protection policies. There is a lot of personal data in schools that need to be secured and must not be disclosed to third parties. Information that is not mandatory requires written consent, which often has to be given by the parents. Teachers are liable to criminal prosecution if they do not obtain these consents prior to use, which is often not easy in practice. Many internet services that we use in everyday life as a matter of course collect a wide variety of data. These are often stored on servers that are not affected by EU data protection law, so that the further processing of these data cannot be prevented. Services that require an individual user account are also a matter of concern under data protection laws. Due to that, digital education in Germany needs many individual technical solutions which have to be developed (for instance in the context of the Digital Pact) and implemented. This needs additional time and funds. From this perspective, the privacy policies inhibit the progress of digital education.

Issue 4: Funding is in question

As described above, the government funded digital education and flexible solutions during the pandemic with the Digital Pact. The progress of recent years would not have been possible at all without it. Before the pact, digitalization in education was only a marginal phenomenon in most schools. There has been just a little advancement. Currently, it looks like the funding will not be continued without a gap, and the national government is giving no guarantee at all if and when the next Digital Pact will emerge. This may have two effects: A discontinuation of the pact would have a negative effect on the existing infrastructure that has been installed in recent years because costs of operation, maintenance and replacement cannot be carried by the states and local authorities (Kultusministerkonferenz, 2023) on their own. If further investments and innovations are to be drastically reduced, the digital transformation would come nearly to a standstill.

Issue 5: The distribution of funds is unfair

It has been mentioned several times already: The status of digital education varies significantly between the individual schools and the federal states. The better the financial situation of a state, the more money it can give to the local authorities, and richer districts can invest more in the digital education of schools. Some schools are very well equipped because they participated in a pilot program, have a sponsor or they regularly get high funds. Only the successful schools are reported by the press and the school ministries again and again. In fact, there are many "black spots" all over Germany where digital education is deficient. Despite the huge shortage of skilled workers, especially in IT professions, Germany is not providing adequate quality digital education throughout the country. As such, a lot of potential is getting lost.

Conclusion

It is hard to imagine that an industrialized country like Germany has so little direct control over its educational system. The states have wide latitude and the schools implement the policies very differently. This can be a strength on the one hand, because in this way regional aspects can be taken up in the school curriculum. On the other hand, this can be a weakness when it comes to megatrends that need the education at all schools to be updated. In such situations, the national government lacks direct influence on the educational system. While the KMK can prescribe new frameworks for states, the specific implementation is left to the federal states and their schools individually. Moreover, as elsewhere, implementation is also a question of money. In terms of finances, the states and the municipalities differ significantly, so that the implementation of innovations in schools also varies enormously.

Digital education is unfortunately a very expensive innovation, as it requires threefold effort:

- Infrastructure must be purchased and its operation incurs ongoing costs. Many existing IT solutions cannot be adopted in schools without enormous effort due to strong restrictions of privacy policies.
- In addition, pedagogical concepts have to be developed to ensure the full potential of digital education. Therefore, in-job teachers have to be further educated and the teacher education has to be updated.
- Aside from that, the digital technology standards develop very fast, so technical solutions as didactical concepts become outdated or insufficient and have to be renewed.

These costs cannot be covered seriously without changing the way of funding schools. The national government did this by updating the basic law of Germany to be able to implement the biggest education investment program in Germany's history: The Digital Pact. It was a stroke of luck that funding was available when the coronavirus pandemic occurred because the need and the option arose at the same time. This constellation significantly accelerated digital education in Germany. It went from stage I, "digitization," to stage II, "digitalization," in most educational institutions. Right now, there is a spirit of further innovation and many projects fostered by the Digital Pact suggest that in the future the education system can reach stage III, "digital transfer," even though the digital education is still at different stages depending on the specific local conditions. However, teachers are suffering due to overload. The lack of supporting technical staff and the administration overheads are pushing them to their limits. The Digital Pact 2.0 has to improve the situation and has to be aware that teachers must once again have an attractive profession to deal with the general professionals' shortage, which even causes a lack of teachers.

Full of hope, all in education are awaiting the continuation of the Digital Pact. Still, the national government hesitates to announce the future of the Pact, and a funding gap seems to appear. The present spirit and many innovations that enhance learning so far are threatened, and the digital transformation could grind to a halt. Now it is up to the government to decide what priority it gives to digital education in times of multiple crises.

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Trends and Issues of Digital Learning in the Hong Kong Special Administrative Region

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Abstract

The Hong Kong Special Administrative Region (HKSAR) government recognizes the importance of Digital Learning (DL) in nurturing future-ready citizens, and has taken steps to promote its adoption in the K-12 education system. The first official strategy document for promoting DL was published in 1998, with a focus on establishing physical infrastructure such as desktop computers. However, the third strategy document in 2008 shifted towards a more techno-centric and human-centric approach to integrating information technology into learning and teaching. A more recent strategy document aimed to equip students with the skills to become self-directed learners and to develop and integrate new pedagogies with existing ones. DL in Hong Kong K-12 education reached the stage of "Digital Transformation" as stated by Luo and Wee (2021) over a decade ago. The features of DL among K-12 students in Hong Kong include a high degree of digital competence and engagement in online activities for schoolwork, leisure, and social networking purposes, the nurturing of higher-order thinking skills, as well as the encouragement of parental and family involvement in DL by the government. Trends in DL in Hong Kong include the encouragement of more sophisticated applications of DL, increasing autonomy in DL, the ongoing emergence of new DL initiatives by schools, more intensive teacher training and competence, and ongoing curriculum transformation. However, this chapter also identifies several issues in K-12 education related to DL, including ethical considerations and consequences of unethical use of digital technology, adverse effects of digitalization, challenges in assessments for DL, the widening digital divide, and a lack of long-term commitment by the government. It concludes by suggesting that a balanced and sustainable approach to DL is necessary to address the challenges and leverage the opportunities presented by the digital world to provide high-quality education for all.

Keywords: digital learning, Hong Kong, digital transformation, K-12 education

Introduction

In the bustling metropolis of Hong Kong, with a population of 7.4 million, basic education covers grades 1 to 12, and the government provides free education for K to 12. The government also supports tertiary education. This paper focuses solely on K-12 education.

Structure of the Hong Kong schooling system

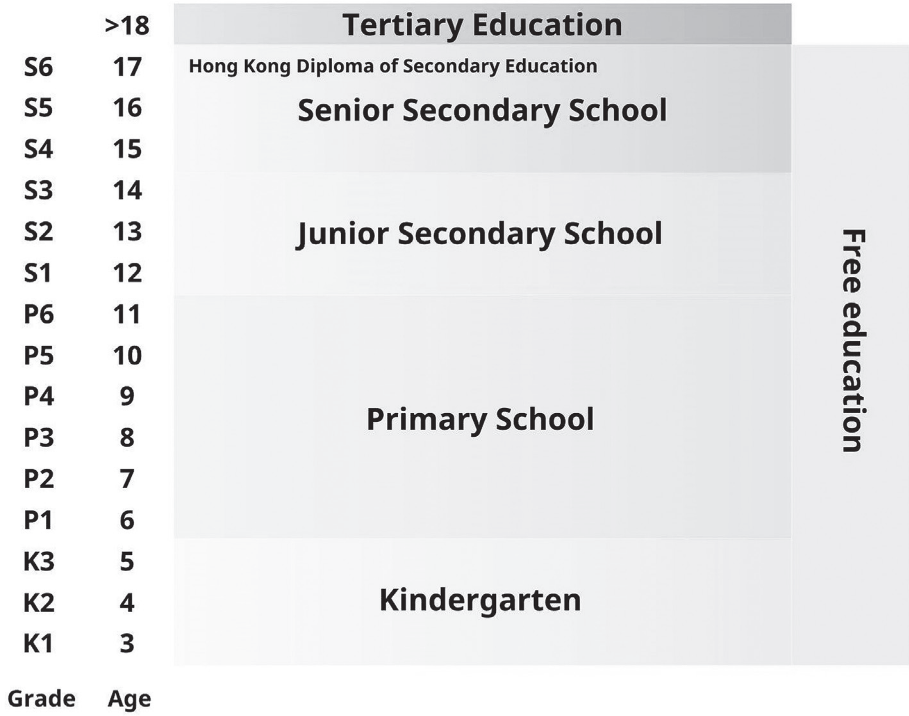
This section provides an overview of the three major levels of K-12 education in Hong Kong: kindergarten, primary, and secondary education.

In Hong Kong, while kindergarten attendance is not compulsory, almost all 3- to 6-year-olds attend kindergarten (Wong, 2015, 2022). There are over 1,000 kindergartens in Hong Kong, all of which are private institutions. Around 80% of these institutions are non-profit-making kindergartens that adopt local curricula, and nearly 97% of local kindergartens join the government's "Kindergarten Education Scheme," offering free half-day services to children (Education Bureau, 2017; Wong & Rao, 2022). Whole-day services are also available but with additional fees. Most kindergartens operate with three levels: K1 (nursery class for 3- to 4-year-olds), K2 (lower kindergarten class for 4- to 5-year-olds), and K3 (upper kindergarten class for 5- to 6-year-olds). Those that join the Kindergarten Education Scheme must follow the government's Kindergarten Education Curriculum Guide, which emphasizes all-round development, including ethics, intellect, physique, social skills, and aesthetics. The curriculum places child-centredness as its core and aims to foster children's interest in learning, positive values and attitudes, self-confidence, and self-care abilities (Curriculum Development Council, 2017a). To achieve five developmental objectives — "Moral Development," "Cognitive and Language Development," "Physical Development," "Affective and Social Development," and "Aesthetic Development" — the Kindergarten Education

Curriculum is designed with six learning areas, namely, “Physical Fitness and Health,” “Language,” “Early Childhood Mathematics,” “Nature and Living,” “Self and Society” and “Arts and Creativity.” The “Nature and Living” learning area includes raising awareness and appreciation of technology and ways of using it to improve modern life.

Hong Kong’s primary and secondary education system consists of four types of schools, with each stage lasting for six years in the public sector. The first three are government schools, aided schools, and Caput schools, which are fully subvented by the government and are run by religious, charitable, or clan organizations. The fourth type, Direct Subsidy Scheme schools, receives funding based on enrolment. Private schools are also available. As of September 2021, approximately 279,700 children were enrolled in 456 public sector primary schools, while around 254,900 students attended 392 public sector secondary schools (Education Bureau, 2022a). The government aims to provide free education to all children, and offer balanced and diversified school education to construct their knowledge, skills, and values for further studies or work. It also aims to promote whole-person development, lifelong learning capabilities, and proficiency in biliterate and trilingual communication among students (Secretary for Education, 2022). One of the government’s priorities is to promote the use of IT in learning and teaching at the primary school level (Secretary for Education, 2022). The latest update on the learning goals of primary education highlights the importance of using information and IT in a rational and responsible manner (Curriculum Development Council, 2022). Secondary education in Hong Kong, on the other hand, aims to provide a balanced education to meet the diverse needs of students, enabling them to develop knowledge and acquire generic skills to contribute to Hong Kong and the nation, and to become responsible citizens (2019). The following diagram illustrates the Hong Kong K-12 schooling system.

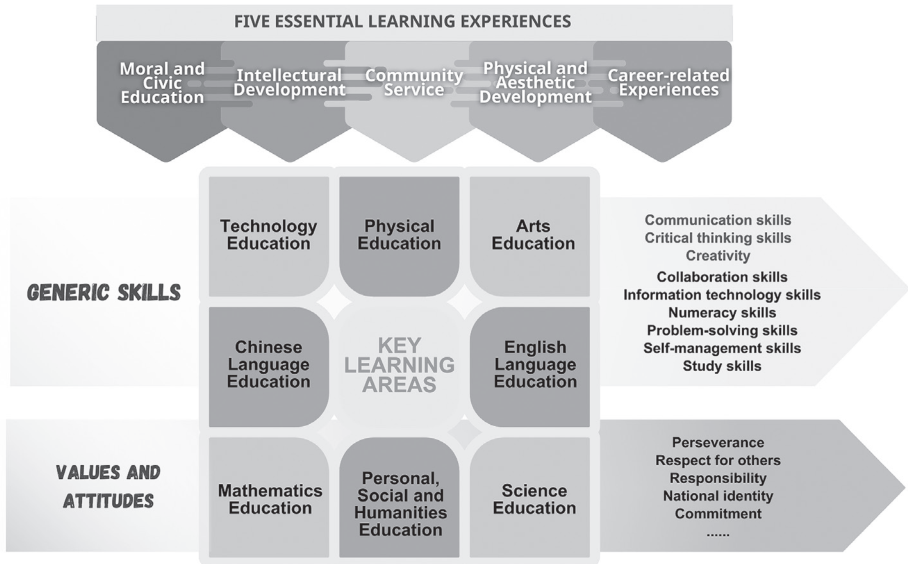
Figure 1 Schooling System of Hong Kong



In other words, the Hong Kong government practically provides 15 years of free education: three years of non-compulsory half-day kindergarten education, nine years of compulsory primary to junior secondary education, and three years of non-compulsory senior secondary education. Tertiary education takes a variety of forms such as higher diploma, associate degree, and Bachelor's degree. As this chapter focuses on K-12 education, the tertiary education system in Hong Kong has been omitted from the above figure; details can be found on the Education Bureau's website at https://www.edb.gov.hk/en/edu-system/postsecondary/index.html.

The curricula from kindergarten to senior secondary school aim at fostering students' whole-person development, and lifelong and self-directed learning capabilities (Education Bureau, 2022a). Despite not directly focusing on digital learning (DL), the diagram below shows that technology education is included as one of the eight Key Learning Areas (KLAs).

Figure 2 The Hong Kong School Curriculum



Note. Adapted from Curriculum Development Council, 2014.

Digital transformation (DX) and current stage in K-12 schools

Luo and Wee (2021) proposed a framework for understanding the different stages of digital learning (DL), identifying three distinct phases. The first stage is Digitization, which involves the conversion of non-digital resources and information into digital format. The second stage is Digitalization, where traditional learning processes and interactions are transformed into their digital equivalents. Finally, the third stage is Digital Transformation (DX), representing the most advanced and innovative phase, characterized by a comprehensive integration of digital technologies to transform education. In the DX stage, digital technologies are used to support strategic decision-making, improve efficiency, and create new learning opportunities, requiring a deep understanding of the school's goals, culture, and processes. This advanced stage also leverages emerging technologies, such as data analytics, artificial intelligence, and others.

Hong Kong's early childhood education has already moved beyond the first stage of Digitization and is currently in the midst of the second stage of Digitalization, where appropriate integration of IT equipment and electronic media is encouraged to assist learning. In primary and secondary education, DL in Hong Kong has also advanced beyond the first two stages, as described in the *Consultation Document on the Third Strategy on Information Technology in Education* (Education Bureau, 2007). The government's e-Textbook Market Development Scheme, launched in 2012, received numerous applications from K-12 schools covering a range of subjects, including Chinese Language, English Language, Mathematics, General Studies, Computer Literacy, Putonghua, Life and Society, and Physical Education. The scheme's popularity and wide coverage across primary and junior secondary levels reflect the enthusiasm of K-12 schools for adopting e-textbooks.

About a decade ago, the Hong Kong government developed plans to enhance already digitalized e-learning resources, develop new pedagogy using digital technologies, and integrate them with existing pedagogy, as described in the 2014 consultation document by the Education Bureau. This document also emphasized capacity building for teachers' professional development in digital education and the involvement of parents and other stakeholders in sustainable development. The principles of learner-focused digital education, stepwise planning, and ongoing curriculum renewal were also introduced in the document. These initiatives demonstrate Hong Kong's commitment to innovative and disruptive education transformation, incorporating digital technologies to enhance teaching and learning. With the adoption of emerging technologies, Hong Kong's DL has progressed to the DX stage, as described in Luo and Wee's (2021) framework.

Several innovative and disruptive education transformation projects in Hong Kong K-12 schools have also contributed to the DX stage. For example, Tavernier (2016) successfully applied the Book Creator, an iPad app, to help 3- to 5-year-old children in kindergartens complete assignments and create sophisticated digital artifacts. Khoo (2016) reported that digital text reading was effective in promoting preschoolers' construction of mathematical knowledge. So and Chen (2018) applied e-learning to Primary 3 students, demonstrating positive changes in their conceptual understanding and evidence-use skills. These individual projects provide further evidence of Hong Kong K-12 education being in the DX stage.

In summary, Hong Kong's DL has advanced through the three stages of Digitization, Digitalization, and DX, characterized by a comprehensive integration of digital technologies to transform education. The government's policies, curriculum documents, and innovative projects all demonstrate a commitment to innovative and disruptive education transformation in Hong Kong's K-12 schools.

The Status of Digital Learning

Contexts of digital learning

The Education Bureau of the Hong Kong government provides funding and resources to support educational institutions at all levels in implementing online learning (Hong Kong Legislative Council, 2020). In 2014, the gross student-to-computer ratios in the primary and secondary school sectors were 4.54:1 and 4.21:1, respectively (Education Bureau, 2014), indicating a high level of student accessibility to computers in schools in Hong Kong.

Hong Kong's primary and secondary school students have also demonstrated a high level of digital literacy. In 2018, Hong Kong ranked fourth in the digital reading literacy achievement of 15-year-olds in PISA, after China, Singapore, and Macao (OECD, 2019). This ranking improved from third place in 2012 (OECD, 2019). These results reflect the effectiveness of Hong Kong's education system in promoting digital literacy among students. This part introduces the major government policies on DL in Hong Kong K-12 schools and how they were influenced by COVID-19.

DL policies, projects/programs, and strategies

The Hong Kong government has a long-standing commitment to promoting information technology in education. The first strategy for IT education in primary and secondary schools was implemented in 1998, followed by the second and third strategies in 2004 and 2008, respectively. The latest strategy, the fourth one, was promulgated in the 2015/2016 school year.

The first strategy, *Information Technology for Learning in a New Era: Five-year Strategy — 1998/99–2002/03* (Education and Manpower Bureau, 1998), aimed to develop students' information processing capabilities, connect them with the world, and transform schools into innovative learning institutions for nurturing student motivation and creativity, as well as to help students form a life-long learning attitude and capacity. The strategy emphasized infrastructure building, such as installing equipment and developing digital learning resources, as well as creating a community-wide culture conducive to using IT for learning.

The second strategy, *Empowering Learning and Teaching with Information Technology from 2004 to 2007* (Education and Manpower Bureau, 2004), focused on empowering teachers and students with DL, enhancing e-schools and e-leadership, and enriching digital learning resources, IT pedagogy development, and community supporting IT in education. This strategy placed more emphasis on human capacity development for DL, both on an individual level and at the school level.

The third strategy, outlined in the consultation document by the Education Bureau (2007), highlighted two trends that were shaping the learning environment. First, there was a growing use of web-based collaboration, including the use of blogs, wikis, and RSS feeds. Second, mobile learning was becoming increasingly popular, enabling learning anywhere and anytime. The consultation document provided examples of innovative educational technologies, such as classroom response systems, portable e-whiteboards, text message alerts sent to mobile phones, multimedia museum guides, and ubiquitous language learning with mobile phones. The government was proactive in integrating IT into K-12 learning and teaching, with the strategy focusing on collaborative, contributory, and creative learning, supported by digital technologies.

The official report of the *Third Strategy on Information Technology in Education: Right Technology at the Right Time for the Right Task* (Education Bureau, 2008) shifted the focus from technical to human aspects of the use of IT in education, aiming for successful integration of IT into education. The strategy focused on collaborative, contributory, and creative learning, which aligns with the DX elements in Luo and Wee's (2021) digital development framework.

The review surveys conducted in 2010 and 2012 involving all school sectors showed that over 70% of primary, secondary, and special schools submitted their responses online (Education Bureau, 2012). The survey found that IT infrastructure had been well set up in schools, including classrooms and internet connections, and schools were increasingly adopting mobile devices such as tablets. Schools were actively adopting IT in their teaching, with over 80% of schools having plans to improve students' learning outcomes. Interactive learning activities using IT had replaced traditional digital resources, indicating strategic decisions and innovative education transformation in the DX stage, as defined by Luo and Wee's (2021) framework.

The Hong Kong government's commitment to promoting information technology in education continued with the promulgation of *The Fourth Strategy on Information Technology in Education* (Education Bureau, 2015). This strategy built upon the earlier strategies and aimed to develop self-directed learning, problem solving, collaboration competency, computational thinking competency, creativity, innovation, entrepreneurship, ethics in IT use, life-long learning, and whole-person development. The strategy included many innovative and disruptive education transformations, as well as strategic decisions, with the overarching aim of unleashing students' power of learning to learn, and enabling them to excel.

The aims of the strategy were to be achieved in various ways, including enhancing schools' infrastructure and operation mode, improving the quality of e-learning resources, enriching the free resources on the Education Bureau's One-Stop Portal for Learning and Teaching Resources, and sharing resources among teachers. The strategy also involved enabling Single Sign-on and integrating e-learning platforms, renewing the curriculum, transforming pedagogical and assessment practices, building professional leadership, capacity, and communities involving parents, stakeholders, and the community of practice, and sustaining a coherent development of IT in education.

The Education Bureau's (2014) *The Fourth Strategy on Information Technology in Education – Consultation Document* indicated the Hong Kong government's determination to tap into the power of IT and equip students to be self-directed learners with talent and virtue. This reflects the government's commitment to implementing DX almost a decade ago by developing new pedagogy using digital technologies and integrating them with existing pedagogy. The document also proposed capacity building for teachers' professional development in digital education and parents and other stakeholders, as well as learner-focused digital education, stepwise planning, and ongoing curriculum renewal. The Education Bureau encouraged the use of flipped classrooms, social network platforms, and technology for interaction, active participation and engagement. The progress of the implementation of this consultation since 2015 was smooth (Census and Statistics Department, 2022b).

The Secondary Education Curriculum Guide Booklet 6D, entitled *Information technology for interactive learning: Towards self-directed learning*, released in 2018 (Education Bureau, 2018), was based on the fourth strategy. This booklet provides further evidence for Hong Kong K-12 schools being in the third stage of DX, as defined by Luo and Wee's (2021) framework. In the existing curriculum, IT was not only used for learning knowledge and skills, but was also a means of building up one's capacity for self-directed learning through interactive learning activities. Self-directed learners were "able to identify their learning needs, formulate goals, and choose resources and strategies for learning" (Education Bureau, 2018, p. 2).

Kong et al. (2014) offered a concise and informative account of the historical development of e-learning in Hong Kong's K-12 education, summarizing the key trends in DL in the region. According to their analysis, there has been a high awareness of the importance of e-learning in the Hong Kong community since the 1990s, and the Hong Kong government has emphasized ''Information Technology for Interactive Learning'' as one of the four key tasks in local curriculum development. ''IT Skills'' were included among the other eight generic skills in the curriculum reform in the 2000s. Kong et al. (2014) identify three documents that marked three distinct stages of information and communication technology (ICT) development for K-12 schools in Hong Kong up to 2013, before the promulgation of the fourth strategy in 2014.

The first stage, from 1998 to 2003, began with the implementation of the *Information Technology for Learning in A New Era: Five-year Strategy—1998/99–2002/03* by the Education and Manpower Bureau (1998), which aimed to build ICT infrastructure on school campuses (such as desktop computers and campus-wide networks), prepare teachers for integrating ICT into their teaching, and encourage community involvement, such as the involvement of parents and tertiary educational institutions. This stage also involved the development of digital learning resources and the provision of ICT facilities in community centers.

The second stage, from 2004 to 2007, began with the release of the second strategy on *Empowering Learning and Teaching with Information Technology from 2004 to 2007* (Education and Manpower Bureau, 2004). This stage focused on promoting students' proper and ethical use of ICT in daily life, encouraging e-learning pedagogical innovations, and for example, through the support of pilot schemes, reviewing resources for e-learning and enhancing training for e-leadership through the organization of activities such as public seminars.

The third stage, covering the period 2008-2013, focused on using the right technology at the right time for the right task, as set out in the *Third Strategy on Information Technology in Education: Right Technology at the Right Time for the Right Task* promulgated by the Education Bureau (2008). The development of this stage was based on three themes. The first was the development of an online repository with curriculum-based digital resources, categorized by subjects, grades, and themes for easy retrieval, search and sharing. The second theme was the development of e-textbooks as self-contained curriculum packages. According to Kong et al. (2014), the Education Bureau promoted school-based ICT education planning through its provision of a four-component resource pack, requiring all schools to develop their own school-based e-learning plans with the support of a one-off grant for infrastructure procurement.

The high priority the Hong Kong government has placed on digital learning in primary and secondary education is evident from the frequent reiteration of digital literacy in various supporting documents. For instance, the pilot version of the *Primary Education Curriculum Guide* released in 2022 emphasizes the need to nurture students' media and information literacy (Secretary for Education, 2022). Similarly, an update on the secondary education curriculum reiterates the importance of career and life planning, given the rapidly-evolving nature of the workplace and the emergence of new jobs in the technology-driven economy (Curriculum Development Council, 2017b, 2021).

In 2000, the Curriculum Development Council of the Hong Kong government promulgated guidelines for schools to organize learning and teaching activities aimed at developing students' capability of using IT. The guidelines proposed five stages covering Primary 1 to Secondary 7, with learning targets involving knowledge, skills and attitude for each stage. Broadly speaking, the stages begin with basic computer operation, awareness of the use of IT in daily life, an interest in using IT to become frequent and sophisticated users of IT, being able to select and employ appropriate IT tools for specific purposes, and being able to critically evaluate the usefulness of emerging IT tools. Although the guidelines focused on students' proficiency in IT skills rather than digital learning, they indicate the Hong Kong government's awareness and determination to advance digitalization in the formal curriculum.

In 2005, the Education and Manpower Bureau published a document on an information literacy framework for the capacity building of learning to learn for Hong Kong K-12 students. This document aimed to complement the earlier curriculum reform document, focusing on developing students' independent learning capability, lifelong learning and whole-person development. The framework defines an information literate person as "one who knows why and how to use information for achieving purposes throughout his/her lifetime... [and who acts] ethically by not plagiarising another's work when presenting the research to an audience" (Education and Manpower Bureau, 2005, p. 7). In addition to learning autonomy and social responsibility, this framework focuses on developing students' capacity for reflective learning and "the necessary skills to comprehend, locate, analyze, critically evaluate and synthesize information and apply their knowledge to inform decisions and problem-solving" (p. 12). This means that higher-order cognitive dimensions, such as metacognition and problem-solving skills and values, are covered. The document recommends a generalized assessment method on both cognitive and affective domains and a school-based implementation of information literacy. The above document provides evidence that DL in Hong Kong K-12 education has long developed beyond the stage of merely mastering IT knowledge and skills. The concerns since the 2000s have shifted to wider coverage, including metacognitive, affective, value and sociocultural aspects.

DL implementation in K-12 schools

Today, DL has been implemented at all levels and in all types of K-12 schools in Hong Kong, including kindergartens, primary schools, and secondary schools. The government has provided support for schools to adopt DL, including the provision of infrastructure and resources, teacher training, and curriculum development. DL has been implemented in all learning areas, including language, mathematics, science, social studies, and the arts.

However, there are areas where DL has been implemented with special emphasis. For example, it has been implemented more extensively in senior secondary schools, where students are preparing for public examinations and further studies. In these schools, DL has been used to provide more personalized and flexible learning opportunities to meet the diverse needs of students, including the provision of online courses, e-textbooks, and other digital resources (Education Bureau, 2018).

Another area where DL has been implemented with special emphasis is in language learning, particularly for the English and Chinese languages. In recent years, the government has launched several initiatives to promote the use of digital technologies in language learning, including the provision of language learning apps, online language courses, and digital reading materials. These initiatives aim to enhance students' language proficiency, improve their reading and writing skills, and promote their interest in language learning.

The main reasons for the special emphasis on DL implementation in senior secondary schools and language learning are the increasing demand for personalized and flexible learning opportunities, the need to prepare students for public examinations and further studies, and the importance of language proficiency in the globalized world.

The impact of COVID-19 on DL

The COVID-19 pandemic has had a significant impact on DL in Hong Kong as in other cities across the globe. The strong DL infrastructure of Hong Kong enabled K-12 education to rapidly transform itself in response to the pandemic. In a longitudinal research study on around 2,000 K-12 students in Hong Kong from 2019 to 2021, Law et al. (2022) noted that the Hong Kong government mandated longer periods of intermittent school suspension, resulting in a radical change from face-to-face to online teaching. This change substantially increased students' time spent on digital technology, both during and after school time, contributing to their development in digital literacy. As Xia et al. (2023) pointed out, Hong Kong schools, like most schools across the globe, could not escape the influence of COVID-19 on school closure.

The Hong Kong government was highly aware of the need for the continuation of education despite school closure. In 2020, the Education Bureau (2020) offered funding to assist K-12 schools in Hong Kong to implement e-learning. Moorhouse and Wong (2022) gathered the views of English language teachers through an online survey and follow-up interviews on the adaptation of their instruction in response to COVID-19. The study found that teachers adopted a variety of asynchronous and synchronous digital technologies and instructional approaches not only for teaching but also for learning assessment and communication with students and parents. Another study conducted by the Hong

Kong Federation of Youth Groups (2020) reported that secondary schools in Hong Kong expressed that the COVID-19 pandemic had increased the amount of time used for e-learning, which was a global phenomenon. However, e-learning that involves interpersonal interactions was not frequently carried out. This suggests that the pandemic has underscored the need for more effective DL strategies that can accommodate the interpersonal and social dimensions of learning.

Digital learning infrastructure

Hong Kong is a highly digitalized society, as reflected by the government's official figures. As of November 2022, the mobile subscription penetration rate in Hong Kong was 301.3%, with a total of 22,550,784 mobile phone subscriptions (Office of the Communications Authority, n.d.a). This shows that on average, each Hong Kong citizen owns three mobile phones. The internet penetration rate of the Hong Kong population has also steadily increased from 88.1% in 2018 to 91.2% in 2022, with a projected rate of 93.4% in 2027 (Statistica, n.d.). Additionally, almost all Hong Kong households (99.1%) were using broadband as of October 2022, and the personal computer penetration rate for businesses of all sizes was 81.0%, with a 95.7% internet usage rate (Office of the Communications Authority, n.d.b). These figures highlight the advantages and convenience that digitalization provides to service sectors such as finance, banking, and education, and enables Hong Kong to maintain its competitiveness among Asian countries (Legislative Council, 2021).

The Hong Kong government has made significant efforts to promote e-learning, including the establishment of WiFi campuses for about 1,000 public sector schools, a review of the curriculum, fostering of professional development for school leaders and teachers, and enhancing the quality of e-learning resources (Census and Statistics Department, 2022b). Compared to other regions, such as Singapore, Taiwan, and Beijing, Hong Kong's strength in e-learning for K-12 education lies in the creation of digital classrooms supported by wireless networking for student-centered learning (Kong et al., 2014). Since the inception of the first five-year strategy of ICT education in 1998, there have been significant improvements in school and home access to ICT in Hong Kong (Yuen et al., 2014). A study by Law et al. (2022) found that students' ownership of a large screen device is positively related to their digital literacy among K-12 students in Hong Kong. The readily available infrastructure contributes to the high digital literacy of Hong Kong K-12 students.

Reviews of the progress of the third and fourth strategies for ICT education in Hong Kong conducted in 2010, 2012, and 2015 indicated that schools have well-established basic IT infrastructure, including classrooms and the internet, and have begun to acquire devices for mobile learning (Education Bureau, 2012, 2015). These efforts demonstrate the Hong Kong government's commitment to promoting e-learning and leveraging its digital infrastructure to enhance education.

Hong Kong has had a solid DL infrastructure for K-12 schools in Hong Kong for over a decade, as reported in the government's 2007 consultation document on the third strategy (Education Bureau, 2007). The report noted that schools had adequate hardware and software, all public sector schools had a broadband connection to the internet, and the student-to-computer ratios were comparable to countries such as the United Kingdom and the United States. Additionally, over 90% of students had access to computers and the internet at home. The report also found that major stakeholders, including school management, teachers, students, and parents, had positive attitudes toward DL. Almost 90% of primary school students and 80% of secondary school students liked to use computers to learn in class, and 85% of primary school students and 60% of secondary school students reported that they liked to use computers to learn beyond school hours. Almost 100% of primary and secondary school students claimed that they possessed knowledge of using computers, reflecting their confidence in their digital literacy. Furthermore, 60% of parents endorsed the use of IT for learning.

Despite positive attitudes towards DL, a survey found that just over 50% of teachers frequently used IT in class in 2005/06, despite the majority of teachers contending that IT could make teaching more effective, and rating themselves as confident in selecting appropriate digital resources to teach (Education Bureau, 2007). Ongoing teacher professional development on DL was included as one of the key actions to be taken in the consultative document. In the 2020/21 academic year, 10,000 primary school teachers and 9,700 secondary school teachers attended 310 IT courses organized by the Education Bureau (Census and Statistics Department, 2022b). Additionally, about 1,500 primary and 1,400 secondary school teachers attended 150 courses listed on the Web-based School Administration and Management System. The same year recorded 480 primary school teachers and 470 secondary school teachers executing duties as IT coordinators/ IT in-charge at school, and more than 1,800 secondary school teachers were teaching IT/ computer studies. With the accelerating development speed in IT in general and for K-12 teaching, more and more relevant teacher training is expected to be provided.

Features of digital learning

Over the past two decades, DL among K-12 students in Hong Kong has undergone significant evolution, resulting in advanced, sophisticated, and innovative developments. Today, students possess a high degree of digital competence, enabling them to engage in online activities for schoolwork, leisure, and social networking purposes. DL in Hong Kong's K-12 education also facilitates the development of higher-order thinking skills. The government has encouraged parental and family involvement in DL, and schools have continued to introduce new DL initiatives, laying a solid foundation for the future of DL developments in Hong Kong's K-12 education. These developments are described in more detail below.

A high degree of digital competence increasing at a rapid pace

The digital competence of K-12 students in Hong Kong is increasing rapidly, as confirmed by various studies and reports. For example, Law et al. (2022) conducted a longitudinal study on the digital citizenship of Hong Kong K-12 students, and found an increase in digital literacy among their participants, which allows them to engage in online activities for schoolwork, leisure, and social networking purposes. The study adopted a comprehensive framework that includes dimensions such as information and data literacy, communication and collaboration, digital content creation, digital safety, and problem solving. The study's findings indicate that digital literacy encompasses much more than knowledge and skills in technology; it also covers collaboration, creativity, safety, and problem solving. Similarly, the survey for progress review of the third strategy found that students' competencies in using technical devices had significantly improved and were comparable to those of European students (Education Bureau, 2012). The same report also describes how IT was widely used in many school subjects, and innovative, interactive, and collaborative learning adopting IT had replaced the reading of traditional digital resources.

In *The Fourth Strategy on Information Technology in Education*, the Hong Kong government pointed out that in 2015, schools in Hong Kong had already achieved an IT-rich school environment, school professional leadership and capacity, and support from community partnerships for DL (Education Bureau, 2015). These factors have contributed to the rapid increase in digital competence among K-12 students in Hong Kong.

Given the above, it is reasonable to expect that the high-speed increase in digital competence levels will continue to be a feature of DL in Hong Kong K-12 schools in the future. Students in Hong Kong are proficient in using digital tools and resources, and they are increasingly exposed to innovative and collaborative learning experiences that foster higher-order thinking skills. As DL continues to evolve, it is likely that digital competence will become an even more crucial skill for success in the 21st century, and Hong Kong's K-12 education is well-positioned to meet this challenge.

Nurturing higher-order thinking skills

Since the implementation of the third strategy, Hong Kong's K-12 education system has placed a strong emphasis on nurturing higher-order thinking skills through DL. Problem solving, collaboration, and self-regulation have been identified as key skills that students need to succeed in the 21st century. The Secondary Education Curriculum Guide Booklet 6D, entitled *Information Technology for Interactive Learning* (Education Bureau, 2018), is an example of how DL initiatives in Hong Kong have shifted towards higher-order learning skills, such as self-directed and collaborative learning. This booklet goes beyond teaching IT knowledge and skills and provides guidance on how to integrate DL into the curriculum to foster higher-order thinking skills.

There are also emerging DL initiatives in Hong Kong that focus on specific higher-order thinking skills, such as analyzing and evaluating (Lee & Lai, 2017), abstract thinking (Kee & Zhang, 2022), decision making, and problem solving (Dawson et al., 2021). Although only the first of these projects involved K-12 students in Hong Kong, it is expected that more similar initiatives will be developed and implemented in K-12 schools with the continuous advancement of DL.

Encouraging parental involvement

Encouraging parental involvement in IT for learning and teaching has been a recurring theme in Hong Kong's K-12 education system since the announcement of the first strategy on information technology in education (Education and Manpower Bureau, 1998). The first two strategies emphasized the importance of communication between schools and parents regarding IT use for learning and teaching. The third strategy added a new dimension of empowering parents with IT knowledge to provide guidance to their children on the ethical and legal use of IT, and to prevent them from engaging in inappropriate online activities. The fourth strategy re-emphasized the essential role of parents in the DL of their children, and recommended ongoing communication and partnership between schools and parents.

Moorhouse and Beaumont (2020) attempted to involve parents in their children's school-based digital learning of English language writing, and reported that parents were involved by viewing and liking the platform, rather than commenting. Parental involvement in digital education has also been advocated as a measure to combat the digital divide, which is the accessibility gap between those who can access computers and the internet and those who cannot (Van Dijk, 2012). Chun et al. (2023) summarized four sets of skills for the digital literacy of parents proposed by Romero (2014) to tackle the issue of the digital divide among K-12 students in Hong Kong: (1) privacy, content, and technology management; (2) communication and socio-emotional skills; (3) creative and problem-solving skills; and (4) lifelong learning to keep abreast of digital literacy skills. They also introduced the government's initiative of the task force review undertaken by the Hong Kong government on home-school cooperation on e-learning and websites for parental digital literacy enhancement.

Research has found that the digital competence of K-12 students in Hong Kong is directly related to family background and parental support (Liang et al., 2021). Therefore, the Hong Kong government advocates for strengthening parental support for their children's digital citizenship. This suggestion concurs with the importance of parental influence on children's digital learning found by Gonzalez-DeHass et al. (2022). Tan et al. (2022) conducted a study during the COVID-19 school suspension in primary and secondary schools in Hong Kong, and found that children with more parental home monitoring and support had higher self-efficacy, acquisition of digital skills, and cognitive-emotional regulation, and were less worried about school resumption after COVID-19.

However, Reichert et al.'s (2020) survey found that only 50% of their participating K-12 students reported receiving parental support for digital learning. Given Law et al.'s (2022) findings that the digital competence of Hong Kong K-12 students is statistically significantly related to student well-being and family socio-economic status, it is essential to encourage family support in nurturing K-12 students' digital citizenship. The Hong Kong government should continue its efforts to involve parents in their children's digital learning and provide them with the necessary resources and support to enhance their digital literacy.

Trends and Issues in Digital Learning

The trends identified in the use of digitalization for education resonate with the features of DL. These trends reflect a more advanced and sophisticated application of DL, with a focus on promoting autonomous and personalized learning. Additionally, there is an ongoing development of initiatives on DL, more intensive teacher training, and ongoing curriculum transformation. They are introduced below.

Trends in digital learning

More sophisticated and diverse use of digital learning

The first trend identified for Hong Kong K-12 DL is the encouragement of more sophisticated and diverse use of digital learning. This includes using DL for higher-order learning, such as metacognition, self-regulation, complex problem-solving capacity, and abstract thinking. *The Fourth Strategy on Infor-*

mation Technology in Education emphasizes the importance of self-directed learning, problem solving, and collaboration among learners (Education Bureau, 2015). However, Hong Kong educators should be aware that there is a wide variety of DL applications available, such as collaborative problem-solving games, self-enhancement of learning through students' self-tracking, and the use of advanced augmented/virtual reality.

To keep up with the rapidly advancing landscape of DL, new DL strategies are expected to be released by the Hong Kong government. These strategies are likely to focus on the more advanced implementation of DL for K-12 students in Hong Kong. For example, future strategies may encourage students to self-develop mobile apps for their own learning, share self-developed apps among students (YP Team, 2020), or even engage in young entrepreneurship with the support of schools and the government (Weng et al., 2022). These initiatives will allow students to develop the digital skills and competencies required to thrive in the 21st century.

Promotion of autonomous and personalized DL

While the third strategy (Education Bureau, 2008) focused on collaborative, contributory and creative learning, the fourth strategy (Education Bureau, 2015) took a step forward by aiming to strengthen students' capacity for self-directed learning and learning autonomy (p. 58). Research has shown that learning autonomy is positively related to digital literacy (Chiu et al., 2022), and DL requires a high level of learner autonomy while fostering it (Kay-Jones & Janvier, 2022). Personalized learning, such as online learning, has been found to be effective in resolving many problems, such as information overload (Chen et al., 2021).

Despite the importance of learner autonomy and personalized learning, they are still not widely addressed in the official documents of the Hong Kong government, particularly the four DL strategies introduced so far. However, with the increasing sophistication of educational technology and the emergence of new learning needs, it is expected that the Hong Kong government, schools, students, parents, and the community will become more aware of the importance of these two concepts in the future development of DL.

Ongoing development of initiatives on DL

As introduced at the beginning of this chapter, Hong Kong K-12 education has seen the development and implementation of initiatives on innovative DL. This trend is set to continue, given the emphasis on innovative learning and teaching by the Hong Kong government. Several recent initiatives implemented in Hong Kong K-12 schools are worth highlighting.

Weng et al. (2022) reported on the effectiveness of real-world problem-based maker education on face masks during the COVID-19 pandemic in promoting student creativity and entrepreneurship in a K-12 school in Hong Kong. Qualitative data showed that students' creativity and entrepreneurship were scaffolded in various ways throughout the learning cycle. Lee et al. (2022) reported on the positive outcome of a project on informal digital learning of English in a secondary school in Hong Kong, finding that personal enjoyment played a larger role in students' willingness to communicate in English than social enjoyment or teacher appreciation. Another empirical study of 330 grade 8 students found that teacher involvement was the most influential predictor of behavioral, cognitive, and emotional engagement in digital learning environments (Xia et al., 2023).

These studies suggest that ongoing research and initiatives on DL in Hong Kong K-12 education are likely to lead to further advancements. As the understanding of DL among K-12 students increases, new opportunities for innovative and effective teaching and learning will emerge. The Hong Kong education system can continue to foster these developments by promoting and supporting research, providing professional development opportunities for teachers, and embracing new technologies and pedagogies that enhance the learning experience for all students.

More intensive teacher training

Teachers play a crucial role in effectively integrating DL into the learning and teaching process to create positive impacts, as reiterated in the official documents of the Hong Kong government (e.g., Education Bureau, 2007). The third strategy (Education Bureau, 2008) prescribes seven success factors for effective integration of IT into learning and teaching for teachers, including continuous professional development, sharing of pedagogical practices, IT-enhanced teaching resources, student-centered learning, catering for learner differences, enjoyable learning experiences, and promoting students' lifelong learning.

Research has consistently shown that teacher support is the strongest predictor of student engagement in terms of cognition, behavior, and emotion (Xia et al., 2023). As suggested by Chong and Pao (2021), teachers can be expected and required to undergo more extensive and specialized training on digital learning with the increasing variety and number of policies and initiatives of the Hong Kong government on DL. This is especially true as the successful integration of IT into learning and teaching heavily depends on teachers' instruction (Moorhouse & Wong, 2022). Schools that participated in the research conducted by the Hong Kong Federation of Youth Groups (2020) expressed that teacher training is a key factor in the successful implementation of e-learning initiatives.

Ongoing curriculum transformation and development of school plans

The curriculum reform surveys conducted by the Curriculum Development Council (2001) and the consultation document of the third strategy (Education Bureau, 2007) revealed that school heads and teachers regarded IT in education as a top means that contributes to the progress in implementing curriculum reform. Key stakeholders, including school principals, teachers, parents, tertiary institutions' centers of IT in education, and the IT sector, have emphasized that the seamless integration of IT into education requires assimilating IT into the teaching of key learning areas (KLAs) of the curriculum. The fourth strategy provided guidelines on curriculum transformation for the effective use of IT in learning and teaching, and specific strategies for individual curricula.

The Hong Kong government has incorporated common teaching and learning strategies for using IT, and specific strategies for individual curricula into the KLA curriculum guides for basic education and the New Senior Secondary curriculum and assessment guides. However, teachers may face workload and time constraints, and are not always able to select and integrate digital resources into their lesson plans (Education Bureau, 2007).

To address this issue, the third strategy (Education Bureau, 2008) included the provision of assistance for drawing up school-based IT in education development plans by the Education Bureau. The importance of a school-based IT plan was reiterated in The Secondary Education Curriculum Guide Booklet 6D (Education Bureau, 2018) after the fourth strategy. Effective school-based IT in the education development plan is expected to integrate IT into learning and teaching across the curriculum, aligned with the school's needs and priorities, and to deploy resources strategically. Developing a good plan involves two main tasks for schools: conducting comprehensive self-review and working collaboratively with stakeholders.

Issues in digital learning

Hong Kong, like many countries with mature development in DL, faces several challenges in K-12 education. These challenges include ethical and healthy use of digital technology, adverse effects of digitalization, challenges in assessments for DL, the widening digital divide, and a lack of long-term planning by the government.

Ethical and healthy use of digital technology

Ethical and healthy use of digital technology is a critical aspect of K-12 education in Hong Kong. UNESCO (2016) stresses the importance of the ethical aspect of digital technology use, and Reichert et al. (2020) advocated for enhancing awareness and understanding of digital citizenship among Hong Kong K-12 students. Despite official documents advocating for promoting the ethical aspect of digital citizenship since 2001 (Curriculum Development Council, 2001), no concrete plans or systematic implementation on this issue could be found among K-12 schools in Hong Kong.

To address this issue, cyber ethics were included in the third and fourth strategies (Education Bureau, 2008; 2015) as the target to empower school leaders, teachers, IT in education support staff, students, and parents in the actual use of IT in education, especially in out-of-school use. However, students still face uncertainties, dilemmas, and temptations in their DL experience. Effective communication between various parties is essential to ensure the ethical use of DL.

Unauthorized use of personal information by others and computer viruses are common problems faced by technology users, including K-12 students. In interacting with others online, students may engage in risky online communications, such as looking for new friends on the internet, making acquaintances with someone they have never met face-to-face, or sending personal information. Cyberbullying, although not a major issue, is also worthy of attention, given its potentially serious consequences for students (López-Meneses et al., 2020; Yang et al., 2018).

Digital literacy plays a protective role for students against adverse influences (Weinstein & James, 2022). Learners with higher levels of digital literacy are less likely to suffer from internet and game addiction and are less likely to be involved in digital security problems, risky online communication, cyberbullying perpetration and victimization. This means that students with higher digital literacy have higher levels of self-protection from adversities. With the increasing risk of online security problems, cyberbullying, and internet addiction, the Hong Kong government updated the "Information Literacy for Hong Kong Students" Learning Framework in 2018 (Education Bureau, 2022b) to include more guidelines on these dimensions.

Adverse effects of digitalization

The adverse effects of digitalization on K-12 education in Hong Kong are a growing concern. Improper use of digital technology has been found to cause mental health problems, internet addiction, game addiction, inadequate sleep, and inadequate physical activity, which have been exacerbated by the COVID-19 pandemic (Alotaibi et al., 2020; Tahir et al., 2021). Increasing cases of internet addiction have been found among K-12 students in Hong Kong, similar to other parts of the world (Sung & Chiu, 2022; Wong et al., 2023). The Hong Kong Federation of Youth Groups (2020) found that e-learning had negative effects on the physical health of students, overuse of electronic devices, and lower learning effectiveness and motivation.

In a recent study on the digital citizenship of K-12 students in Hong Kong, Law et al. (2022) identified schoolwork, leisure, and social networking as the major online activities both at school and at home. The study also identified five specific uses of digital devices during the day, including communicating with family and/or friends, leisure activities at school, schoolwork at school, leisure at home, and schoolwork at home. These trends align with the educational value of online activities, in contrast to the adverse effects identified in other locations (see Daoud et al., 2021). This finding emphasizes that while there may be potential health hazards associated with DL, the healthy and proper use of digital technology for learning should be acknowledged and promoted.

Challenges in assessments for DL

Assessing students' digital learning skills remains a challenge not only in Hong Kong but globally. The Hong Kong government has proposed formative assessments such as classroom observations, homework, and project assignments (Curriculum Development Council, 2000; Education Bureau, 2014; Pan et al., 2022). However, no systematic guidelines or evaluation criteria have been offered.

The COVID-19 pandemic and online teaching have accelerated the need for transformation in L2 assessment (Chen, 2022). Teachers play an important role in technology-mediated remote assessment (Chen, 2022). Pan et al. (2022) reported the preliminary results of a large-scale digital literacy performance onsite assessment in Hong Kong in online-supported and online self-directed modes during the COVID-19 pandemic. The challenges they identified included tighter school schedules due to the need to carry out assessments, schools' willingness to provide support, equipment and connectivity issues, and the provision of different testing modes. An important issue highlighted by Pan et al. (2022) is cheating in high-stakes tests. They noted that online proctoring or other high-technological solutions to prevent cheating may not be feasible in K-12 schools due to insufficient bandwidth and lack of infrastructure.

Despite the government's endorsement of and encouragement to use e-assessment in the Hong Kong K-12 sector, Pan et al. (2022) raised the issue of inequity in remote assessments, which discriminate against students from low-income families who are less resourceful in terms of technological equipment.

Widening digital divide

The COVID-19 pandemic has highlighted and exacerbated the digital divide among Hong Kong K-12 students. The digital divide can exist not only among individuals but also among households, businesses, and geographical areas, according to the OECD (2001). Among Hong Kong K-12 students, lack of access to technology and digitally illiterate parents are two aspects of the digital divide commonly identified (Chun et al., 2023). Students and schools that participated in the research conducted by the Hong Kong Federation of Youth Groups (2020) also shared the view that e-learning would widen the gap between students from rich and poor families.

In 2021, only 75.2% of poor families (i.e., those with monthly household income below HK$10,000) had access to the internet, which is relatively low compared to over 90% of other income groups (Census and Statistics Department, 2022a). In 2019, the same percentage was only 71%, which again was relatively low compared to over 90% of other income groups (Census and Statistics Department, 2020). Differences in ICT use patterns were also found between K-12 students of lower and higher-income families in Hong Kong, with students of lower-income families spending more time using a computer at home, and students of higher-income families having more access to ICT (Yuen et al., 2014).

To address the widening digital divide, the Education Bureau has implemented the "Computer Recycling Scheme" and the five-year "i Learn at home" program since 2011 (Yuen et al., 2014). However, despite the government's efforts in terms of resource support (mainly financial) and initiatives (such as computer recycling), students from low-income groups still suffer from basic problems, including the inability to own a computer and lack of internet access (Chun et al., 2023). In a review of digital citizenship development in Hong Kong conducted by Reichert et al. (2020), it was identified that 30% of the participating students studying Primary 3, Secondary 1, and Secondary 3 had no access to desktops, notebook computers, or tablets. Chun et al. (2023) noted that the effectiveness of the e-learning implementation emphasizing "Bring your Own Device" remained doubtful, given the significant percentage of K-12 students who do not have access to proper devices.

It has been almost a decade since the Hong Kong government implemented its last strategy on Information Technology in Education, and it is high time for a new policy to be in place for the future implementation of new initiatives on IT in education in Hong Kong.

Lack of long-term planning by the government

Hong Kong has reached a mature stage of digitalization with sophisticated adoption in education. However, there is a need for more systematic review, future planning, and incorporation of new initiatives identified from advanced locations. While policies to promote digital citizenship are suggested in reports in a piecemeal manner, digital citizenship has never been included in the strategic plans of the government or its implementation. Macro planning and policy on digital citizenship should take into consideration a myriad of factors, including student needs (on both learning and leisure), family environment, devices available, and types of guidance (e.g., ethical use of the internet) to be given to students.

Two other relevant issues are the lack of software support and the uneven development of DL among school sectors. The curricula at all levels of education in Hong Kong are unique due to contextual influence, and at the same time, Hong Kong is a small market. Much overseas-developed software for digital learning may not be applicable in Hong Kong, and investors are unwilling to invest in the small market due to uncertainties of economic return. Due to reasons such as the nature of the curriculum, the learning needs of students caused by characteristics such as age, teacher attitude and knowledge, and school support, the speed and coverage of digitalization in Hong Kong are expected to be uneven.

In the surveys reported in the *Consultation Document on the Third Strategy on Information Technology in Education*, stakeholders suggested that a clear strategy in the school development plan, together with support from school leaders, is required for the successful integration of IT into learning and teach-

ing (Education Bureau, 2007). This means that DL is subject to school leadership, and there may be uneven development among schools in terms of DL development.
Government efforts to promote digital learning should be accompanied by a long-term plan that considers the unique needs of Hong Kong's education system and the resources required to achieve these goals.

Conclusion

This chapter provides an overview of the Hong Kong K-12 schooling system, and highlights the advanced stage of Digital Transformation in which innovative and disruptive education transformation is being implemented. However, evidence suggests that pre-school and kindergarten education in Hong Kong is not as developed compared to primary and secondary schools in this third stage of Digital Transformation. This chapter argues that the Hong Kong government can make more strategic decisions for innovative and disruptive education transformation, given that many of these innovations are initiated by individual teachers, schools and academics.

Hong Kong has always been at the forefront of DL infrastructure, and the four strategies on information technology demonstrate the government's commitment to the development of DL for K-12 students. Generous financial and consultative support has been provided by the government, coupled with ongoing teacher professional development on the latest developments in DL. This chapter identifies the features of DL, including a high degree of digital competence increasing at a rapid pace, nurturing higher-order thinking skills, and encouraging parental involvement.

This chapter suggests several trends in DL for K-12 students, including more sophisticated and diverse use of digital learning, promotion of autonomous and personalized DL, ongoing development of initiatives on DL in individual schools, more intensive teacher training, and ongoing curriculum transformation. However, the chapter also raises five issues in K-12 education in Hong Kong in terms of DL, including ethical and healthy use of digital technology, adverse effects of digitalization, challenges in assessments in DL, the widening digital divide, and a lack of long-term planning by the government.

Despite these challenges, the historical development of DL in Hong Kong K-12 schools, including its planning and implementation, the response of Hong Kong K-12 schools to the COVID–19 pandemic in terms of DL, their DL infrastructure, and the features, trends and issues in DL, consistently indicate the uniqueness of the DL of Hong Kong K-12 schools. The first uniqueness is a well-established infrastructure, especially in terms of WiFi networks. The second is the government's responsiveness to the rapidly changing DL landscape, which is reflected by the variety of themes of the four strategies on DL promulgated to date. The third uniqueness is the high levels of digital literacy and competence of students, which are supported and facilitated by the prevalence of communication technology in the Hong Kong community at large.

K-12 teachers in Hong Kong welcome and are enthusiastic about adopting DL, which is reflected by the widespread implementation and the ongoing emergence of innovative pedagogy. However, as with students in many technology-savvy cities, K-12 students in Hong Kong are exposed to risks of physical and mental health hazards caused by technology addiction, privacy infringement, financial losses, and criminal commitments caused by unethical use of technology.

This chapter concludes that Hong Kong should continue to strive for a balanced and sustainable approach to DL, addressing the challenges and leveraging the opportunities presented by the digital world to provide high-quality education for all.

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Trends and Issues of Digital Learning in Israel

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Abstract

This chapter explores the trends and issues of digital learning in Israel, with a focus on the challenges faced by educators in adapting education systems to the digital age. The authors, Prof. Orit Avidov-Ungar and Oded Busharian, discuss the importance of digital leadership in promoting the effective integration of technology into teaching, and highlight the significance of institutional norms and environmental conditions in this process. They also examine the impact of the COVID-19 pandemic on distance learning in Israel, and the need for a systematic transformation of teachers' understanding of education, student evaluation processes, digital infrastructure, and more. Ungar and Busharian suggest that Israel has a strong foundation for digital transformation in education. Israel's MOE, together with the academic community and some strong and innovative private and third sector actors, have invested heavily in bringing this change about. However, there are still some major obstacles to be overcome: the reliance on existing educational practices by many teachers; the cultural and ideological divide between different sectors in Israeli society; the fact that many teachers still do not see how digital technology can help transform their discipline; and the centralized nature of Israeli education and the reliance on high stakes standardized testing.

Keywords: digital learning, distance learning, educational technology, digital transformation, Israeli education

Theoretical Introduction

Adapting education systems to the digital age is a huge challenge for educators, both technologically and in terms of optimal integration in teaching (Tondeur, 2018). This type of process requires attention to the perceptions of educators regarding the integration of technology, its usefulness in teaching, its user-friendliness, and their sense of self-efficacy in its use. It also requires attention to the institutional norms and environmental conditions that promote its integration into teaching (Tondeur et al., 2019). The effective adoption of digital learning in education systems requires the development of digital leadership, particularly in light of the insights from the period for emergency remote online learning during the COVID-19 pandemic (Traxler, 2023). Fullan and colleagues (2020) discussed the integration of digital learning through three stages of change: (1) adapting to the disruption, (2) navigating towards a return to routine accompanied by uncertainty, and (3) creating an educational vision and designing new educational models based on the insights of the time.

The new reality of the digital revolution creates opportunities for innovative learning that presents the education system and teachers with new challenges (Avidov-Ungar & Amir, 2018; Collins & Halverson, 2018). Thus, education systems in Israel and elsewhere strive to incorporate innovation into teaching, to adopt digital learning as a routine part of teaching and learning, and to bring about a change in the school environment in order to equip students with skills and tools suitable for the 21st century (Mioduser et al., 2003; Nurmalisa et al., 2023).

Implementation of digital learning

For over two decades, education systems worldwide have been intensively engaged in attempts to introduce and integrate innovative technologies into schools to promote digital learning in the educational space. The desire for innovation and the use of technologies in education stems from two motives, namely the pressure from parents and policy makers to improve and innovate, building on the belief that learning and teaching can be improved through digital learning, and the recognition of the role of the education system in equipping students with the skills they need to be ready for the competitive globalized economy (Avidov-Ungar, 2010, 2018; Cuban et al., 2001; Davies & West, 2014; Hayak & Avidov-Ungar, 2023).

The international organization, International Society for Technology in Education (ISTE), proposes operative indicators for teachers and digital leaders. The indicators reflect the power of technology to create a transformative revolution in teaching and learning, to accelerate innovation and to be used to solve complex problems. Five elements can be found in the list of indicators: (1) the use of technology to increase equality, inclusion and digital citizenship; (2) motivating colleagues to create a vision, strategic plan and ongoing evaluation for the transformation of digital pedagogy; (3) creating a culture that encourages innovative use of technology; (4) building teams for continuous integration of technology to support learning; and (5) the function of the leaders as role models (Crompton, 2017).

Models for implementing innovation in teaching

Several theories and models explain the assimilation of innovation in teaching, including that of digital learning. Some of these emphasize the adoption of the innovation from the perspective of the individual (Luo & Wee, 2021; Rogers, 2003; Sherry et al., 2000); others are based on the decision-making and its influence on the degree of integration of technology in teaching (Davis, 1989; Fishbein & Ajzen, 1975).

For example, Rogers' (2003) innovation diffusion theory presents a series of factors that influence the adoption or rejection of innovative technologies. The model classifies five stages of innovation efforts: Innovators, Early Adopters, Early Majority, Late Majority, and Laggards. Sherry and colleagues (2000) expanded on Rogers' model and proposed five paths of adoption and integration of technology in teaching, where teachers undergo a cyclical process during which they develop from a learning teacher to a teacher leader.

Davis et al. (1989) developed the Technology Acceptance Model (TAM) based on the theory of calculated action (Fishbein & Ajzen, 1975). The model discusses the perceived benefit of incorporating new technologies (Davis et al., 1989). According to this model, two factors influence the degree of integration of the new technology when it is presented to users: the perceived ease of use, that is, the degree to which one believes that using a certain system will be free of physical and mental effort, and the degree of perceived usefulness, that is, the degree to which one believes that using a certain system will improve one’s work.

The difficulties of implementing digital learning in education systems

Despite the clear need, the frequent opportunities, and the great potential inherent in learning and teaching technologies, the implementation of digital learning in education systems may encounter significant resistance and barriers and end in only partial implementation (Avidov-Ungar, 2010; IGI Global, 2023). While first-order barriers such as adequate technological infrastructure and the availability of devices are being resolved in most populations, second-order barriers such as digital literacy, pedagogical-technological knowledge, culture and perceptions of technology continue to be a challenge and even an obstacle (Blau & Shamir-Inbal, 2017; Ertmer & Ottenbreit-Leftwich, 2013; Paulus et al., 2020).

In an attempt to break down the barriers and overcome the challenges, and due to the high costs of assimilation and implementation, educational organizations often choose the "innovation islands" model. In this model, the innovation is implemented in limited areas of the organization with the aim of spreading from there, or through pilot programs which are supposed to teach everyone and allow for a smooth, slow, and controlled transition for innovation throughout the organization. In practice, these methods often allow only a partial application of technology, so that even technology-rich schools do not effectively integrate technology in teaching and learning (Avidov-Ungar, 2010; Davies & West, 2014).

Professional development of teachers to integrate digital learning

Intelligent use of current technological tools may improve teaching and learning and thus lead to more efficient and effective teachers' professional development (PD) (Tondeur et al., 2019). In Israel and elsewhere, in recent years, a variety of training courses, ideas, innovative tools and models have been integrated into the PD system. These enable the use of technological tools to implement digital learning in teaching and learning in schools (Avidov-Ungar et al., 2020).

One of the accepted frameworks for promoting PD and improving the assimilation of digital learning in schools is the Professional Learning Community (PLC). The purpose of such communities is to improve the expertise and professionalism of their members using communal social practices such as peer learning, supporting shared understandings and openness to change. Research shows that these practices enable the promotion of creativity and innovation of teachers within an open dialogue between colleagues. Beyond that, the PLC enables the assimilation of entrepreneurship and the dissemination of innovative teaching ideas and methods among teachers, including the integration of digital learning as part of the implementation of the challenges of the 21st century (Avidov-Ungar, 2018; Avidov-Ungar & Konkes Ben Zion, 2019; Fox et al., 2021; Liu et al., 2022).

The Status of Digital Learning in Israel's Education System

Education in Israel is mandatory between the ages of 6and 18. The system is divided into four main stages: pre-elementary, elementary, junior high school, and high school. Pre-elementary education in Israel is not compulsory, for children aged 3 to 5. About 537,000 children (about 20%), attend state pre-elementary education in Israel (Ministry of Education, 2022). Its main aim is to provide young children with the necessary social and emotional skills to prepare them for elementary education. Pre-elementary education is provided in nurseries, kindergartens, and day-care centers.

Elementary education (Grades 1 through 6) is compulsory for children aged 6 to 12. Almost half of Israel's students, about 1,120,000, attend state elementary education (Ministry of Education, 2022). Its main objective is to teach children the basic skills of reading, writing, and arithmetic, as well as to provide them with a broad knowledge of other subjects such as science, social studies, and the arts. Students in elementary education are taught mainly by a single teacher who also serves as a homeroom teacher, with the exception of specialized subjects such as music, mathematics, English and physical education.

Junior high school in Israel covers Grades 7-9 and focuses on building a strong foundation of general knowledge and skills, while high school (Grades 10-12), also mandatory, is more specialized and prepares students for university or advanced vocational training.

High school education provides students with the opportunity to study for matriculation examinations, which are required for admission to higher education institutions in Israel. The examinations cover a wide range of subjects, including Hebrew as first language, English, mathematics, history, and the sciences. At the start of high school education, most students choose one or two subjects that they would like to study in greater depth as their majors.

Table 1 below shows the distribution of students across the various levels of education for the 2022 school year.

Table 1 Distribution of Students across Education Stream and Levels (in thousands) – Data for 2022

Pre-elementary	Elementary	Junior high	High school	Higher education
537	1,117	309	474	356

While the education system in Israel is relatively centralized, it is also divided geographically into education districts. There are eight districts: one for each of the three major cities in Israel (Tel-Aviv, Jerusalem, and Haifa); three geographic districts (northern, central and southern), one for rural education (the Hityashvuti district – in Hebrew: the rural settlements' district); and one for ultra-orthodox education (the Ultra-Orthodox district is relatively new and does not have geographic borders, but is instead cultural). These districts are responsible for implementing the MOE's policy, and for overseeing the learning activities in their respective regions.

In addition to the general system described above, Israel's education system also has several unique components that reflect the country's diverse cultural and religious landscape. These include Arab education, religious education, and ultra-Orthodox education (see Table 1).

Arab education is the education system for Arab citizens of Israel, who make up about 20% of the population. About 558,000 students, or 22.7% of all students, study in Arab-state schools. Arab schools are taught in Arabic and follow the same curriculum as Jewish schools, with the addition of courses on Arabic as first language, Arab history and culture, and Islamic studies. Arab education faces several challenges, including a shortage of resources and infrastructure, low academic achievement rates, and a lack of integration with the Jewish education system.

Religious education in Israel is divided into two main streams: state religious education and independent religious education. State religious education is provided by the government and is designed for students who identify as Orthodox or religious Zionists. About 18.8% of Jewish students (15% of all students) study in the state-religious schools. The curriculum in these schools includes both secular and religious studies, with a focus on Jewish history, culture, and values. Independent religious education is provided by private religious institutions and is largely focused on Talmudic studies and religious law.

Ultra-Orthodox (otherwise known as Independent religious) education is a unique system of education that is provided to the Ultra-Orthodox Jewish community in Israel. Around 27% of Jewish students (22% of all students) study in the Ultra-Orthodox education system. This education system is largely self-contained and separate from the general education system, and it is focused on the study of religious texts and the development of a strong religious identity. Ultra-Orthodox schools are typically gender-segregated and have a low emphasis on secular studies, with a focus on religious education and Torah study. The figures of attendance in the various streams and levels of education within the Jewish sector are summarized in Table 2 below.

Table 2 Students in the Jewish Sector, Divided by Religious Affiliation

Education stream	Pre-elementary	Elementary	Post-elementary
Ultra-Orthodox	31%	31%	17.4%
Sate religious	21.6%	18.8%	18.2%
State general	47.4%	50.2%	64.4%

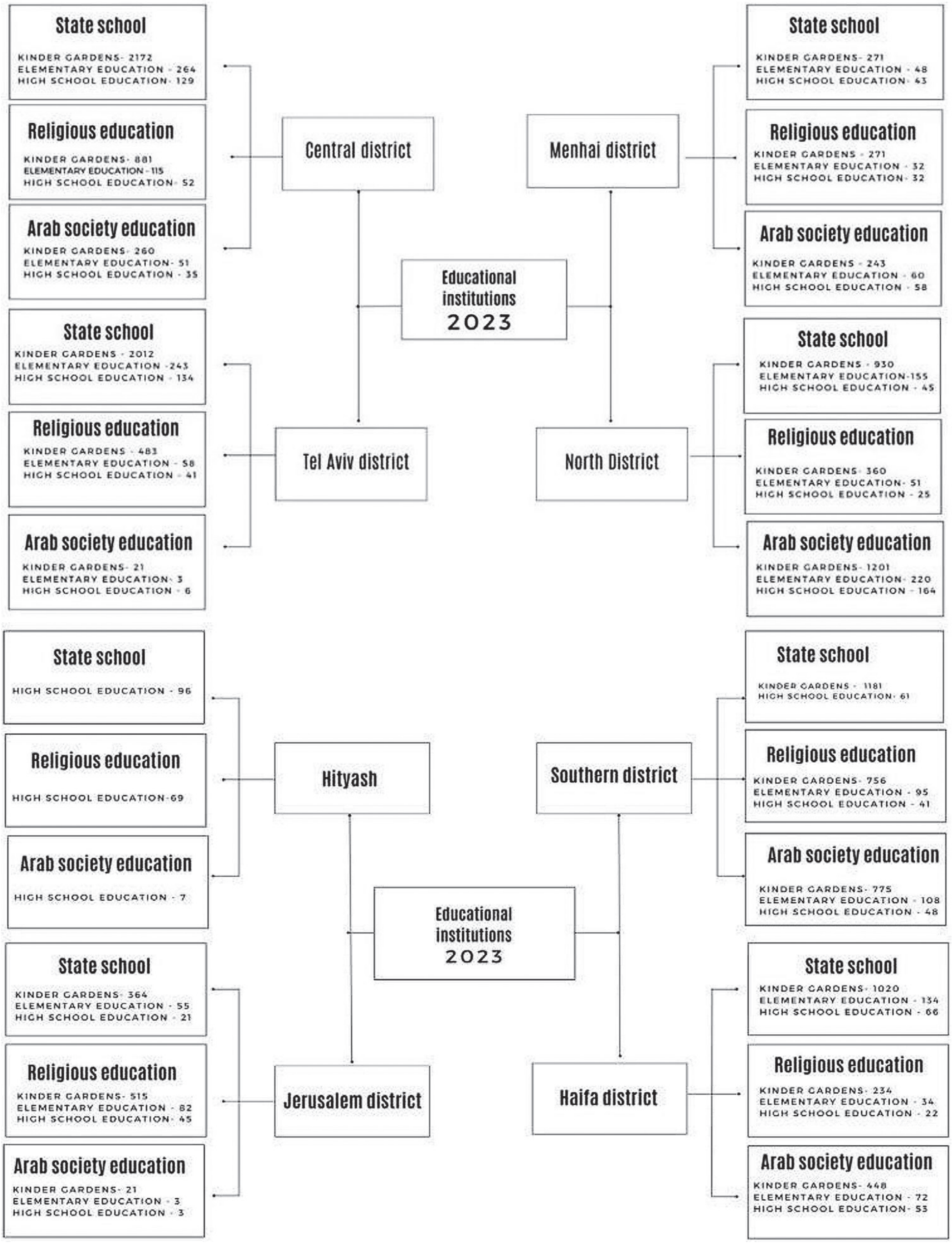
It should be noted that the description in the previous three paragraphs does not reflect the entirety of the complexity of Israeli society and its education system. The Ultra-Orthodox community, for example, is further divided into Hasidic and non-Hasidic (or Lithuanian) Judaism, and the Hasidic sect is further subdivided into many different groups, each with its own educational creed and its own schools (Yeshivas). Arab-speaking society is also subdivided between Christians, Muslims, northern and southern Bedouin, and Druze.

Israel's education system faces several significant challenges. One of the most pressing is the achievement gap between different socioeconomic and ethnic groups. There is a significant disparity in educational outcomes between Jewish and Arab students, as well as between students from different socioeconomic backgrounds. Another major challenge is the cultural and ideological divide between the sectors. This divide makes it almost impossible to provide a coherent educational narrative, and even harder to have a narrative compatible with a modern liberal democratic society. This challenge also affects Israel's digital education status, as will be elaborated in the "challenges" section of this chapter.

In addition to formal and informal education programs, Israel has a strong system of higher education institutions. The country has several universities and colleges, including the world-renowned Hebrew University of Jerusalem and the Technion – Israel Institute of Technology. Israeli universities are known for their research and innovation in fields such as biotechnology, computer science, and engineering.

Here in Figure 1, you can see the structure of the Israeli education system.

Figure 1 The Structure of the Israeli Education System



The use of digital technology in Israeli schools: Education level (age) comparison

In Israel, the use of digital technology in education is more common and more advanced in later stages of education. In kindergartens, the use of digital technology is still in its infancy. While most kindergartens do have a working computer (90%) and an internet connection (60%) and use digital records of the children, at least some paperwork is still done by hand (Zilka, 2018). The use of digital technology for educational purposes per se is limited to the use of WhatsApp groups with parents to share photos and plan activities.

The main reason for the abovementioned state of affairs is the impression, shared by preschool education practitioners (as well as many parents) in Israel, that early exposure to digital technology is not necessarily something to be encouraged. A second (related) reason is that, setting aside theoretical concerns, children at those ages do have less use for digital technology than their older counterparts. For these two reasons, Israel's MOE limits the amount of time children can be exposed to the internet: up to 1 hour a day, no more than 3 days a week in kindergarten second grade, and up to 2 hours a day, no more than 4 days in a week in the third grade (MOE, 2013).

Now, as mentioned above, in elementary and junior high schools, the level of use of digital technology in education is mostly determined by the individual teacher and the principal. This means that about 80% of the uses of the technologies are limited to augmenting and enabling existing educational practices. Examples of such practices are in-class lectures using presentation formats such as PowerPoint or Google Slides, or out-of-class reading from digital books.

In high schools, two contradictory effects influence the adaptation of digital technology in education. On the one hand, at this age most Israeli students already have sufficient understanding of the English language, as well as some level of digital literacy, to benefit from digital learning. On the other hand, at this educational level the pressures of high stakes standardized examinations are high, and this prevents the use of progressive educational practices in general, and the use of transformative educational technology in particular, as will be explained in the final section of this chapter. These two effects together create an environment in which digital technology is mostly used to support existing educational practices (digitalization) rather than to transform them (digital transformation).

The highest level of digital education in Israel can be found in higher education. In the wake of the COVID-19 pandemic, Israel's higher education sector has witnessed a shift in its approach to teaching and learning through the widespread adoption of digital tools and platforms. Israeli universities and colleges have successfully transitioned to online and blended learning models, effectively leveraging technology to ensure continuity and quality in education delivery.

By utilizing advanced digital platforms, such as virtual classrooms and online collaboration tools, institutions have successfully overcome geographical barriers and reached a larger audience of students, both within Israel and internationally. The availability of recorded lectures, interactive learning materials, and virtual simulations has empowered students to engage with course content at their own pace, enhancing their educational experience.

On this subject, it is worth mentioning the Open University in Israel. This academic institute aims to provide access to higher education to all students, regardless of place of residence or socio-economic status. Established in 1974, it has been offering distance education to a diverse student population since the late 1990s. With an enrollment of over 46,000 students, it represents a significant segment of the higher education landscape in the country. The institution's flexible learning model has been successful in attracting a diverse student body, with approximately 40% of its students being first-generation tertiary education learners, and over 25% coming from underserved populations.

Digital learning in teacher education in Israel

The higher education system has to be involved in the integration of digital learning in teaching and learning. Although it takes time to assimilate the changes, a budget for this is guaranteed over time. It can be said that the State of Israel, through the Israel Innovation Authority, the Council for Higher Education, and the Ministry of Education (MOE), is promoting the assimilation of digital learning in higher education in general and in the academic institutions entrusted with teacher training in particular.

The Council for Higher Education issued a number of "requests for proposals" for the budgeting of academic institutions that wish to offer suggestions on how to promote digital learning in the teaching processes in academia. These requests for proposals allow the academic institutions to propose moves for the training of the academic staff in the universities to adopt digital learning, including the use of digital tools in teaching-learning processes. In addition, within the framework of the "requests for proposals" academic institutions may offer and develop courses such as MOOC courses that are based on asynchronous online learning. These courses enable collaboration between different academic institutions and also enable the exposure of content and lecturers to multiple students.

Also, specifically in the academic institutions that deal with teacher training, there is a program called "PRIZMA" (in the sense of “point of view”). In this program, every academic institution engaged in teacher training has the option of appointing an academic position holder, usually a faculty member, whose job it is to lead the implementation of pedagogical innovation among the academic teaching staff at the institution. This appointee’s role is to lead the adaptation of teaching that integrates digital learning among the students who are the future teachers in the education system.

In the charter of the requests for proposal sent to academic teacher training colleges in Israel, the colleges may offer unique courses for the training of the faculty, the development of lesson plans based on digital learning, and more. In addition, using these budgets, the college may purchase digital learning tools that have an annual subscription cost, for use over time.

Contexts of digital learning

The main nationwide policy influencing digital education in Israel is "the National Digitization of Education program" or the national program to adapt the education system to the 21st century, which was launched by the MOE in 2010. The goals of the program were to close the (then) existing digital gap between Israel and other OECD countries in terms of digital education, to bring Israel education in line with international standards in this field, and to close the technological gap between Israel's schools and Israeli society.

The program was implemented gradually, along two vectors. First, geographically, it started with schools in the periphery (the north and south districts) and then continued toward the center of the country. Second, it began with elementary schools, continued to junior high and then to high schools.

In the first 10 years, the main effort of the program aimed to improve digital infrastructure in schools. This involved increasing the number of computers per class, improving ICT infrastructure, improving teacher understanding of the use of digital technology in education, increasing technical support available for teachers, improving access to digital learning materials, and appointing a designated coordinator for digital learning in schools.

Within the state and state-religious education systems and, to some extent, the state-Arab education, the quality and quantity of physical digital infrastructure has indeed been dramatically improved thanks to the program. Most teachers in participating schools also reported in an evaluation survey that the schools had sufficient digital resources (Ratner et al., 2015). Later in this chapter we will discuss the sectors that did not manage to benefit as much from the program.

Over the last 5 years, the National Digitization of Education program has continued to operate, but has changed in a few ways. First – it is no longer optional, but mandatory for schools to "go digital." Second, the emphasis changed from physical digital infrastructure to managerial and pedagogic infrastructure. For instance, in the central education district there are 150 elementary schools (out of around 400) which participate in the computational thinking program.

Teachers in Israel have an option to participate in dedicated professional development programs dealing with digital transformation of education. In is estimated that around 40% of teachers choose to do so. However, in terms of teachers' (and principals') understanding of digital technology and the role it may have in transforming education, the program's success remains unclear. While most teachers and principals learned how to use technology to improve and augment existing educational practices, they did not (and do not) make full use of its potential.

An example of this problem can be seen in the PISA 2018 research, where, while 75% of principals reported that a platform to support digital online learning existed, only 25% reported that the teachers were encouraged and rewarded for implementing such learning, and most (55%) reported that the teachers did not have the necessary skills to do so. This will be elaborated in the final section (discussing issues and challenges to digital learning in Israel) of this chapter.

Another important part of the context of digital learning is the organizations that develop digital learning tools in the country. This is even more important in Israel, since many of the available tools are in English and are not necessarily useful for Israeli students, at least not in primary schools. Fortunately, Israel is a "startup nation" and has a very prosperous high-tech sector. Consequently, it has quite a few educational technology developers.

Chief among those is the Center for Education Technology (CET). CET is a community interest company and is by far the largest developer and provider of educational technology in Israel. CET has been instrumental in developing online learning environments, enabling students to access educational content anytime and anywhere, thereby promoting inclusivity and bridging the digital divide.

CET also provides teachers with training, resources, and guidelines to effectively integrate technology into their classrooms. They strive to promote collaboration among educators, students, and parents through digital platforms. CET also conducts research and development to identify emerging technologies and innovative pedagogical approaches.

The status of digital learning in Israel

In this section, we will discuss the current implementation of digital learning in Israel's education system. In accordance with the terms defined by the book's editors, we will distinguish between digitization, digitalization, and digital transformation. Digitization will mean converting non-digital records and information into digital format and the enhanced uses of these data. Digitalization involves the conversion of processes or interactions in education into their digital equivalents. Digital Transformation will refer to uses that are innovative and fundamentally change educational processes, including making decisions to support the use of digital technologies.

Digitization: Digital student records have been in use in Israel for over two decades. Those records have revolutionized the way information is stored and managed in Israel's education system. Traditional paper-based records have been gradually replaced with digital platforms and databases, allowing educators and administrators to access, update, and analyze student information more efficiently. These records encompass a wide range of data, including academic performance, attendance, behavior, and personal details.

Israel's education system also has a relatively strong digital information management system. School records for all K-12 stages are kept in the MOE database and can be used by policy planners in the MOE headquarters. Digital information management supports educational research and policy development. Large-scale data analysis allows policymakers and researchers to identify educational trends, evaluate the effectiveness of interventions, and inform evidence-based policy decisions. This data-driven approach contributes to continuous improvement and informed decision making in Israel's education system.

In addition to the information management systems provided by the MOE, Israeli school headmasters also undergo specific training and professional development in data-driven decision making. For example, in the central education district, all headmasters have day-long meetings with their superintendents and RAMA professionals in which they study the subject. The National Authority for Measurement and Evaluation in Education (RAMA) was established in order to help the education system in Israel to be the best in achieving the results it has defined for itself, and to allow Israeli students to possess knowledge, skills and values adapted to the challenges of the future. RAMA is an independent intra-governmental authority, which reports directly to the Minister of Education, in the status of an enhanced reference unit in the Ministry of Education. Since its establishment in 2005, the authority has been collecting, analyzing and distributing diverse, validated and professional data, designed to support decision-making processes and large-scale change processes. RAMA is the leading body and the professional guide of the education system in the fields of measurement and evaluation. The authority acts as a professional, objective and independent entity, serving all stakeholders in the education system and beyond, including administrators, teachers, parents and student, who seek to build a better future for the State of Israel.

Digitalization: As mentioned above, digitalization is the use of digital technology to complement and improve existing educational practices. Within this scope lies a wide range of uses, including class management, e-learning, teleconferencing, digital blackboards and presentations, digital reading materials and more.

In Israel, the effort to integrate digital technology to improve and augment contemporary educational practices is still a work in progress. On the one hand, the MOE offers teachers and schools various avenues for such digitalization. On the other hand, actual implementation of digitalization in schools still depends on the knowledge and attitudes of individual principals or even individual teachers. Overall, while it is possible to assess that about half of Israeli schools and teachers implement some sort of digitalization in the classroom, a great deal of the potential of digital technology still has not yet been tapped into.

One type of digitalization that does see frequent use in Israel is learning management systems (LMS). Israel's MOE provides those working in education with access to various Moodle-based LMSs. These platforms provide a centralized hub for teachers to create and distribute digital resources, assign and grade tasks, and facilitate online discussions. LMS platforms promote blended learning, allowing students to access course materials and assignments remotely. They also encourage interactive and collaborative learning experiences through features such as virtual classrooms and discussion forums.

The shift from traditional textbooks to digital reading materials is a good example of the fact that although digital technology is implemented, it has not transformed educational practice as it might do in the future. On the one hand, digital textbooks, e-books, and online educational resources are available for students and teachers both via the MOE, and on the internet. These resources provide students with up-to-date information and are easily accessible on various devices, reducing the burden of carrying heavy physical books. On the other hand, most of the existing digital learning materials are not far from a simple digital copy of existing physical books. Features such as internal and external hyperlinks, multi-media user experience, interactivity or adaptability do exist in some disciplines, but are not regularly used in classes. Various challenges that are impeding the use of more advanced features of digital learning materials will be discussed in the relevant section.

Other digital technologies and digital platforms are also being used to augment existing teaching practices. Quiz-generating programs such as Quizlet or Kahoot! are regularly being used in classes. However, the way they are most frequently used is as a game in which the teacher poses a question (or questions), and the students answer them. While this is a step up from other teaching techniques, these same apps could be used to allow for constructivist learning. For example, students might be asked to devise the questions (and answers) themselves.

Digital transformation: Digital technology has the potential to radically transform educational practices. It can be used as part of student-centric education, to allow students to work together, to construct their own understanding of the study material and to have agency over their own learning. In order for that to happen on a national scale, teachers, principals, and policymakers need to work together to create a systemic change in how the education system works.

In Israel, such transformation is still far from happening. While it is possible to see some teachers and even some schools changing how they think about and practice education, the large majority still use technology only to augment existing educational practices. Moreover, while the MOE does invest a lot of resources into promoting the use of digital technology for educational transformation, some existing policies work in the opposite direction and make such transformation difficult to achieve.

Beginning with the COVID-19 period, the MOE (via the education districts) set out to change teachers' perceptions of digital learning. During dedicated professional development sessions, teachers learn up-to-date models of digital technology use in education such as the SAMR model (Blundell et al., 2022) or the TPACK model (Rodríguez Moreno et al., 2019). Again, data regarding the effects of the professional development are hard to come by, but the goal is to get 30-40% of teachers to understand and adopt new models of digital transformation (as "early adopters").

One example of a school that does make use of digital technology to transform its educational practices is "Alterman Tichonet" (named after Nathan Alterman - Israel's national poet) high-school in Tel-Aviv. This is a "paperless" school – all its learning and practice material are online. It uses technology to enable project-based leaning, problem-based learning, and collaborative learning. It has a robotics lab on campus and an R&D center.

The consequences of the COVID-19 pandemic for the implementation of digital learning

The COVID-19 pandemic accelerated digital learning in schools in Israel. The State of Israel succeeded in the transition to distance learning in a manner worthy of praise thanks to several measures that were carried out even before the outbreak of the pandemic. However, some of the advances made during the pandemic have been scaled back in the period since then.

Some of the advances made during the pandemic are: distance learning policy and procedure, establishment of a "cloud infrastructure" of learning materials for all educational institutions, leadership of officials with an emphasis on ICT coordinators who managed the distance learning in schools, systematic and orderly professional development for ICT teachers and a variety of fields of knowledge that integrate digital literacy, and an annual practice anchored in a mandatory CEO's circular of distance learning in all schools.

An example of technology that was accelerated during COVID-19 but is currently underutilized in the Israeli education system is teleconferences for the purpose of blended or distance learning. In Israel, like in other countries, the pandemic accelerated the adoption of teleconferencing tools in education. Platforms such as Zoom, Microsoft Teams, and Google Meet were widely utilized to conduct virtual classes. Those platforms enabled real-time interaction between students and teachers. Remote learning thus overcame geographical barriers, allowing students to access quality education from anywhere in the country.

However, since the end of the pandemic and the curfews imposed to prevent its spread, the mandate for schools to perform distance learning has ended as well. Today, the use of teleconferencing in education is limited mostly to some parts of higher education and a few private or experimental schools (which will be discussed in the following section).

It should be noted, however, that efforts are being made, at the educational district level, to preserve the advances made during COVID-19. For example, the central education district has a few days a year when schools go back to distance online learning (as an exercise). This is considered first to be a part of the skills needed for future workers, and second, part of Israel's preparedness for future possible crises.

During COVID-19, the use of digital cloud environments to share documents and store the "organizational memory" of schools, as well as the use of virtual environments such as "Google Classrooms" became very common. It is estimated that around 80-90% of schools used such digital tools effectively. And again – this statistic dropped drastically post COVID-19, and it is estimated to be around 40-50% of schools now.

Another example of changes that were scaled back is the diverse range of digital content for all age groups, provided by the MOE to meet the needs of various sectors. This included digital books, models for distance learning, and an online broadcasting system that was established for learning core subjects, cloud environments and educational apps. In addition, the schools were required to change their perception of the methods of assessment to include alternative assessment, and high schools were also required to conduct online examinations. Although all those learning materials and environments remain post-COVID, their use is now miniscule compared to the pandemic period.

Some changes, however, have remained and continue to influence the use of digital technology. An example of this is the budgeting of computers and internet infrastructure, with an emphasis on access to libraries, for students who could not afford them before. During the pandemic, over half a billion NIS were invested in strengthening such physical digital infrastructure. That is, laptop computers and wireless internet access were provided to the students' homes mainly in peripheral areas, but also in the center of the country, where needed.

Throughout the duration of the pandemic, the teaching staff studied and developed professionally in a wide variety of courses to promote practices of synchronous and asynchronous learning. For example, all teachers participated in a series of mandatory district-based online training sessions for a large audience of teachers every day, twice a day. As another example, teachers were provided with a series of training sessions for the communities within a local authority.

While the knowledge and skills that the teachers acquired during those professional development sessions remains theirs, and still affect their usage of digital platforms to this day, the participation in these sessions decreased dramatically when COVID-19 ended. It is estimated that only around 40-50% of teachers take advantage of the opportunity nowadays.

The COVID-19 pandemic has highlighted the importance of digital literacy skills at both the teacher and student levels. As a result of the pandemic, digital learning has become an integral part of the education system in Israel, and it continues to develop with the aim of shaping the future of education.

Digital learning infrastructure

Digital learning in schools is very much dependent upon several components of digital learning infrastructure. One of those components is, of course, physical infrastructure, but other components, which are as important for effective use of digital learning, are the ability and knowledge of school leaders, the existence of accessible courses and other software components, the assessment of digital skills, and the professional development of the teachers. All of these components will be analyzed in the following section.

Leadership and budget: The ICT and Technology in Education Division within the Technological Education Administration in Israel's Ministry of Education leads the field of digital technologies in teaching and learning, and is responsible for writing policy, including in reference to protection and information security and for providing technological solutions for the schools, which includes budgets for equipment and internet infrastructure. Over the past few years, there have been calls to join the ICT program, which includes large budgets, and beginning with the 2016 fiscal year, schools receive budgets through a unique budgeting system (called GEFEN – the Hebrew acronym for "administrative pedagogical flexibility") that allows school administrators broad flexibility in choosing extra activities that are suited to the school's unique needs.

In addition to the special budgets routed toward digital infrastructure during the COVID-19 period and "National Digitization of Education program," the MOE has allowed in recent years for school leaders to select their own route to digital transformation. As part of the new "Gefen" (Hebrew acronym for

"Pedagogic-managerial flexibility"), principals receive a dedicated budget to spend on whatever digital technology they choose.

Another critical infrastructure for digital transformation of schools is the role of the techno-pedagogical or computation coordinator in schools. About 90% of schools in Israel have a teacher who takes this role. The coordinators are responsible for leading pedagogical and organizational transformation in school. They receive dedicated professional training, and additional pay for that goal.

Course design and delivery: Schools in Israel may teach through online courses on secure digital platforms and tools to create a learning sequence in routine and emergency situations. They use learning management systems (LMS) such as Moodle / Google Classroom / Microsoft Teams to enable relevant, meaningful, and adapted learning for each student.

Student success in digital learning: One of the goals of using virtual spaces is to provide learners with success-oriented experiences, thereby increasing their motivation to learn. To this end, the Ministry of Education in Israel makes educational websites available to schools such as the "Springboard" program that provides lessons and individual or group support for students to reduce gaps. There is also the "Bagroup" program to help small groups of high school students prepare for matriculation examinations and more. Schools teach lessons dealing with digital literacy as part of the curriculum in order to train learners to succeed while working on a variety of digital platforms.

Assessment and analysis: Evaluation of student performance and data analysis are carried out in schools in Israel via platforms that make digital content accessible. These also provide students with immediate feedback for the student as well as creating learning reports for the teacher. The LMSs map the students' achievements and allow the teacher to provide a tailored response to each student within each class. These digital tools make it possible to reach data-driven decisions that lead to improvement in student performance.

In addition, the MOE has recently begun implementing a digital testing format for the matriculation examinations in some disciplines. This format is meant to allow cost-effective non-standardized testing, and therefore to allow testing of deep learning and transferable 21st century skills and capabilities. Official data regarding the use of this option is not yet available, but it is estimated that by 2025, almost all tests in the humanistic learning fields will be taken digitally. This is expected to directly influence digital transformation in high schools, and indirectly encourage such transformation in lower grades as well.

Professional development of teachers and staff: The Ministry of Education in Israel invests in the professional development of the teaching staff through a variety of channels: courses at Pisgah centers (regional institutions for teacher PD throughout the education system), courses at schools (known as the Learning Staff Room), national online self-study courses, and group learning in professional learning communities that use hybrid (synchronous and asynchronous) formats. All courses are required to comply with a standard that requires the lecturer to have an accompanying online space that serves as a model for the teachers and ensures the integration of digital literacy into the training process.

Technological infrastructure: The Ministry of Education in Israel provides all schools with fiber optic internet bandwidth and connectivity to support online learning. In addition, the Ministry provides an information security mechanism that includes a password system with uniform identification for all students in the education system as well as for the teachers. The Ministry of Education provides laptops to students who cannot afford them, and encourages learning in the BYOD (Bring Your Own Device) model, in which students bring to school their own digital device such as a laptop or iPad for learning in school.

Features of digital learning

Strong foundation for the use of digital records: Israel's education system has a few important features when it comes to digital learning. First, it has a **strong foundation for the use of digital records to make decisions in education**. An important part of advancing this use of data was the establishment of the National Authority for Research and Evaluation in education (known by its Hebrew acronym - RAMA). The authority was formally established in 2006, following recommendations of a government-appointed Dovrat Committee. During the last 15 years, RAMA has undergone many organizational changes.

Today, RAMA is responsible for the ongoing evaluation of the education system as a whole. This includes, among other things, overseeing and managing the participation of the education system in international assessment projects, developing indicators and various measurement instruments to suit the system's needs, assisting schools with internal evaluations as well as conducting evaluations of national education programs.

RAMA also provides schools with tools for internal evaluation of their own strengths and weaknesses. These tools are suited to evaluate both the general goals of the national curricula and specific school goals. They include online adaptive tests and tasks for students, questionnaires for teachers and administrators, and a collection of "evaluation items" to discern students' understanding of core subjects. RAMA also informs interested school staff about the proper ways to use these evaluation tools and understand the data collected by them.

Advanced school data management: One notable feature of Israel's digital record-keeping and usage that has seen great development in the last decade is **school data management**. This came via the implementation of the MANBAS (an internet-based school management system). This system can be accessed by school administrators from every internet-connected computer. The system has numerous applications that are gradually being added. At the teacher level, it allows its users to manage student evaluations, report on lesson progress, students' attendance and behavior. At the staff level, it manages the school timetable and the status of school staff, reports on unusual events (e.g., accidents), and school security, and can generate a wide variety of other reports and certificates. It is currently in a pilot phase of offering services for the students' parents as well.

Digital records are thus used to facilitate data-driven decision making in education. Educators can analyze student data collectively or at an individual level to identify trends, implement targeted interventions, and personalize instruction. This evidence-based approach enhances educational outcomes and supports the continuous improvement of teaching practices.

Lastly, the MOE also provides a way for the general public to access information regarding schools and school districts via transparency in the education system. This system includes indicators on school climate, dropout rates, teachers, and other school staff, learning in schools, academic achievements, and technology usage. These data are presented both in numerical format, and in easily understandable graphs. They can also be presented comparatively.

Strong connection between the MOE and the academic community: A third feature in this vein is a **relatively strong connection between the MOE and the academic research community**. Firstly, almost all educational data are made available for academic research via the MOE's online research room, where approved academics can access data about all aspects of Israel's education system collected in the last 15 years (at least). The data first undergo an anonymization process to ensure that individual privacy is maintained.

Another important connection comes from the Office of the Chief Scientist in the MOE; as the central hub for scientific research and innovation in the education sector, it serves as a vital conduit for knowledge exchange and collaboration. Its primary purposes are to enable effective communication between researchers, scholars, and policymakers, ensuring that evidence-based findings and insights from academia inform the development and implementation of education policies. By fostering these connections, the Office of the Chief Scientist allows policymakers to make informed choices that are grounded in research.

Moreover, this Office also plays a pivotal role in channeling policy priorities and challenges to the academic community. It serves as a key platform for policymakers to communicate their needs, concerns, and aspirations to researchers, encouraging them to conduct targeted studies and investigations that address pressing issues in education. This cooperative approach enables policymakers to tap into the scholarly resources of the academic community, fostering a two-way flow of knowledge and expertise. By actively engaging with academics and researchers, the Chief Scientist's Office aims to ensure that policies are evidence-based, relevant, and aligned with the evolving needs of the education sector. In addition, since 2003, the Israeli Academy of Science and Humanities has had a large unit whose goal is to provide advice to the government in the field of education. This is done by bringing research-based knowledge to the attention of decision makers for use in deciding on policy and improving Israel's education system.

This unit, named "Yozma" (the Hebrew word for "initiative") has various channels of activity: expert committees which tackle complex challenges and fundamental issues of ongoing concern to the education system and in which many entities are involved; work groups consisting of both Ministry of Education managerial and field staff as well as expert scholars that are established to develop a specific product, brief research reviews aimed to support specific policy decisions, and more.

Trends and Issues in Digital Learning

Like most education systems worldwide, the Israeli education system is constantly evolving and changing. The changes are affected by the cultural, structural, and political environments of which the education system is a part. In this section, we will examine some of the major trends in digital learning in Israel in the past decade, as well as some of the issues and challenges facing the effort to digitally transform the Israeli education system.

Trends in digital learning

In the ever-changing landscape of education in Israel, some important changes have taken place in the past 10 – 15 years, and some are still in progress. The major ones, in the opinion of the authors of this chapter, are:

- **The improvement in physical digital infrastructure:** as mentioned above, since 2010, Israel's MOE has been conducting the National Digitization of Education program as part of its effort to adapt the education system to the 21st century. Thanks to this program, the physical digital infrastructure in schools in most sectors of the country has dramatically improved.

- **The building of a "pedagogical database" for digital transformation:** As mentioned previously, the main effort of the MOE in the second decade of the 21st century sought to improve the physical digital infrastructure for schools. Now, while this has not been achieved for all sectors, and is still an ongoing effort, the focus of the MOE's efforts has shifted. Today, the main effort is going into building a comprehensive online databank of digital tools, activities, and learning materials. This effort is led by the professional pedagogical unit of the MOE, and therefore deals more with pedagogical advancement than with technologies.

- **The move to digital data management and decision making:** During the first decade of the 21st century, Israel's education system has mostly completed the move to digital student records, digital management tools, and digital information management. However, in the past decade, further substantial advancement has been made. Israel's education system has made significant strides in digital information management, encompassing various areas such as curriculum planning, teachers' professional development, and educational research. This progress has enhanced administrative efficiency, promoted data-driven decision making, and improved overall educational outcomes.

- **Acceleration of digital use in teacher education:** In recent years, digital learning in teacher training has significantly accelerated as part of the assimilation of digital learning in higher education in general in Israel. Teacher educators have realized that digital learning must already be integrated into the academic learning processes of students in all fields, and even more so in the academic programs for teacher education. It is known that these processes take time, but the policy, prioritization and budgeting in this regard have put these issues on the agenda, thereby giving impetus to the integration of digital learning in Israeli academia. It can be said in this context that relatively speaking, in Israel's higher education system, the assimilation of digital learning is at a medium-to-high level and is getting better all the time. The issue is on the academic-pedagogical agenda and is constantly developing, and this is clearly reflected in the allocation of dedicated budgets for this purpose.

- **Gradual opening of the Jewish orthodox society to the digital world:** as we will see below, one of the major obstacles to digital learning in Israel is the fact that the Jewish ultra-orthodox sector is very closed off and abhors the use of digital technology. In the last few years, and especially since the COVID-19 pandemic, this may be starting to change. The pandemic, and the school closures that came with it, forced many in this community to be exposed to digital technology. This process is still very much in its tentative stages and may still be reversed over time, but it definitely cannot be ignored.

Issues in digital learning

Conservative perceptions of the educational process: The main reason for the sluggish progress toward digital transformation is not actually (directly) related to knowledge or attitudes toward technology, but rather **to perceptions of the educational process as a whole**. Most teachers and headmasters in Israel still regard education as a process by which knowledge is transferred from the teacher to the students (OECD, 2019; Zohar & Busharian, 2020). Even when a theoretical understanding of current educational theory (e.g., constructivist or social constructivist theories) exists, it is difficult for teachers to rise above their imprinted methods of teaching – the ways in which they themselves were taught in school and how they have been teaching for many years.

Lack of understanding of the potential of digital education: In addition, even when teachers do understand the need to apply a student-centric design and student-centric learning, they do not always **understand the ways in which digital technology can help achieve this goal in their particular discipline**. In other words, they do not always have the pedagogical-content digital knowledge. It should be noted that Israeli teachers (like teachers in most countries) have a lot on their plates. The same can be said for Israeli principals. They do not usually have the time or the resources to invest in trying to figure out the current educational technologies and how to best use them in class. This means that even when the MOE or third sector NGOs make an effort to enable easy access to digital tools that may lead to digital transformation, the teachers sometimes do not have the time or resources to learn how to use them in a pedagogically optimal manner.

Now, as we mentioned, the MOE does invest considerable resources in providing easily accessible digital content of the type that might transform Israeli education. Nevertheless, some education policies still exist that are making such transformation (on a systemic scale, at least) difficult, if not impossible. First and foremost among such policies is Israel's high stakes evaluation framework.

High-stakes examinations: In Israel, by the end of 12th grade, every high-school student is expected to take a comprehensive set of matriculation examinations encompassing almost all disciplines (some mandatory and other elective majors). **These are very high-stakes examinations,** since their scores will determine if the students can continue to higher education, and in which colleges or university faculties they may enroll. Moreover, these scores are also part of the teachers' evaluation and may affect possible bonuses, and the average results for individual schools are published online. In other words, the results of these examinations are also high stakes for teachers and principals.

All of the above would not be such a problem if not for two facts: first – it is very hard to evaluate "deep learning" with standardized examinations, which are usually better at assessing surface level understanding of the content. Second – the examinations assess a huge amount of information. In order to teach such huge amounts of information (on a superficial level), teachers have to resort to "old school" methods of teaching, and therefore constructivist learning is often abandoned.

It should be noted that the MOE does allow alternative assessment options in certain disciplines for schools that have the knowledge and resources to implement them. These may include technology-based matriculation examinations and project-based evaluation. However, these options require major resources from the schools, including having a sufficient technological infrastructure and teachers' completion of a special professional development course. Although the use of alternative assessment tools is definitely a step toward digital transformation, they are still very much the exception rather than the rule.

The incentive for digital education content creators: A second policy that makes digital transformation hard has to do with **the incentive that the MOE provides for digital education content creators**. Currently, every school receives a certain budget aimed at purchasing digital content. However, the content creators receive a fixed sum for every class level in every school that uses their content. Schools can, of course, choose to pay more for the content from their own budget, but the MOE only pays a fixed sum. The result of this policy is that content creators have less incentive to invest in quality content (beyond a certain point). Since they cannot ask for a higher price, they sometimes cannot afford to do so.

The fractured nature of Israeli society: Another major obstacle for digital transformation of education in Israel comes from **the fractured nature of Israeli society as a whole**, and Israel's education system in particular. As a result, two sectors of the education system lag behind mainstream education in terms of digitization, digitalization and digital transformation. Those sectors are the Bedouin clans in the south of the country and Jewish Ultra-Orthodox communities. Both of these sections are roughly 10-15 years behind in terms of digitization, each for its own unique reasons.

For the Jewish Ultra-Orthodox communities, the main issue with digitization is **ideological**. This society is based on two principles: isolationism and ultra-conservatism. This means, first, that any unsupervised exposure to the outside world is considered suspicious, and second, that any new technology is met with resistance. Digital technologies and ICT in particular have both unwanted qualities – they are new, and they facilitate uncensored communication with the "outside" world. Thus, they are rejected by the adults and excluded from the education of the youth.

That being said, two things should be noted. First, despite appearances, this society is not a single bloc - it has many sub-groups. These groups, while connected by the idea of strictly adhering to the ancient Jewish laws – the "halacha" – have varying attitudes toward Israeli society as a whole, and varying levels of antipathy toward any kind of technology.

Second, as mentioned above, the entire ultra-orthodox community in Israel has been undergoing major shifts in the last few years. They are becoming a larger percentage of the Israeli population. This growth forces them to play a larger role in the public sphere, and even shape that sphere – both roles they were very reluctant to play in the past. It is too soon to tell how these changes will affect their society in Israel (and Israeli society as a whole), but it is already clear that this effect will be dramatic, and that it will change the way most members of the ultra-orthodox community deal with digital technology.

Lack of infrastructure: There are two main reasons for the lack of digital use in education in the southern Bedouin population. The first reason is **infrastructure, or lack thereof**. About one-third of the Bedouin population in the south resides in unrecognized illegal settlements which largely do not have access to proper educational infrastructure (such as adequate classrooms) and definitely not adequate ICU infrastructure. But even for the other two-thirds who live in legal and recognized settlements, there is a big gap in education funding both at the local and the national levels. Therefore, the ICU infrastructure for them, while more readily available than in the unrecognized settlements, is still sorely lacking.

The second roadblock in the use of digital technology for educational purposes within the southern Bedouin society is **cultural**. Bedouin society has a very tribal and conservative culture. This culture clashes with modern forms of education management and makes it harder to place competent administrators and principals in schools. This, in turn, affects many aspects of education, including the use of digital technology.

Regarding the direction in which the use of digital technology in the Bedouin schools is heading, it is possible to identify two contrasting trends. On the one hand, the MOE is implementing a 5-year plan to improve and equalize the state of educational infrastructure in the Israeli-Arab sector, including, of course, the Bedouin sector. As part of this plan, every local authority belonging to that sector is expected to present its needs, and funds will be diverted to meet those needs. This means there is at least hope that the digital infrastructure for that sector will improve in the near future.

However, when it comes to the cultural elements of Bedouin society, the road ahead is not as clear. The ongoing Israeli-Arab conflict, trends of Islamist radicalization and increased connection to the Palestinian population, all contribute to the continuing cultural gaps between the Bedouin and general Israeli society. On the other hand, both third sector NPOs and the Israeli government are investing billions of shekels in an effort to modernize and integrate the Bedouin population into Israeli society.

One relevant characteristic that the Jewish Ultra-Orthodox and southern Bedouins have in common is a **genuine distrust and suspicion of the government as a whole, and specifically the MOE**. Without getting into the historical and institutional reasons for that distrust, this is another reason why many of the efforts to integrate digital technology (on all three levels) into schools are met with resistance.

Conclusion

In conclusion, Israel's education system has been undergoing major changes in terms of the use of digital technology in education. Currently, most schools and teachers are using digital technology to improve and augment contemporary educational practices. At the national level, Israel has a strong connection between the MOE and the research community, and a robust foundation for data-driven decision making.

On the other hand, while the Ministry of Education offers teachers and schools various avenues for digital transformation, the actual implementation of digital technology to transform education in schools still depends on the knowledge and attitudes of individual principals or even individual teachers. About half of Israeli schools and teachers implement some sort of digitalization in the classroom, but much of the potential of digital technology has still not been tapped into.

In the last 15 years, a few important positive changes have occurred in Israel's digital education landscape. First, there has been a massive improvement in physical digital infrastructure. The Israeli MOE has been actively working to improve the digital infrastructure in schools since 2010. Second, we have seen an increased use of digital technology in later stages of education and especially in teacher education. Third, there is an ever-greater usage of digital data management and decision making. Fourth, a massive undertaking, led by the professional-pedagogical units of the MOE, of building a "pedagogical database" for digital transformation with activities, lesson plans, apps and more is underway.

Unfortunately, Israel still faces some major social, structural, cultural and pedagogical challenges in its effort to allow digital technology to actually transform education. The cultural and ideological divide between different sectors in Israeli society makes it difficult to provide a coherent educational narrative that is compatible with a modern liberal democratic society. This challenge affects the development of a unified and inclusive education system. This divide is especially seen when it comes to the southern Bedouin sector, and the Jewish Ultra-Orthodox sector, both of which lag far behind in the use of technology in general, and digital technology in education in particular.

A second issue is that many teachers and principals have not yet fully understood modern educational theory, and the educational needs of 21st century children. This is a problem mainly because the actual implementation of digital transformation in schools still relies on the specific teacher in class or on the school principal. This relates to a third challenge – the fact that many teachers still do not see how digital technology can help transform their classroom practices in their discipline.

A fourth issue preventing digital transformation in Israel comes from established educational policies. First, the reliance on high stakes standardized testing makes it hard for teachers and parents to think in terms of advanced learning theories – and it is therefore very hard to make the transition to it, with or without digital technology. Secondly, the highly centralized nature of Israel's national education system makes it hard (and unprofitable) for content creators to create high-quality innovative educational content.

In summation, Israel, at least in the national secular and national religious sectors, has a strong foundation for digital transformation. It is possible that in the near future, we will see more and more schools undergoing such transitions. However, this still requires some major systemic shifts in Israel's educational policies and culture. It remains to be seen whether such changes will actually be made.

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Trends and Issues of Digital Learning in Korea

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Abstract

This chapter aims to explore the trends and issues in digital learning in Korea, showcasing the country's progressive efforts primarily driven by the Master Plan for ICT in Education. Notably, Korea has taken significant strides towards digital transformation, embracing innovative changes in education through digital technology. The COVID-19 pandemic accelerated the adoption of various online learning platforms, facilitating a smooth transition to remote learning. As the 4th Industrial Revolution unfolds, Korea has implemented new initiatives like the 2022 Revised National Curriculum, the Digital-Based Educational Innovation Plan, and AI digital textbooks to revolutionize pedagogical approaches and equip students and teachers with essential 21st-century skills. The chapter examines Korea's digital learning ecosystem through six elements, encompassing leadership and budget, course design and delivery, student success in digital learning, evaluation and analytics, teacher and staff professional development, and technology infrastructure. The Korean government's persistent efforts have resulted in digital learning environments that foster meaningful and flexible learning experiences. Key trends include the integration of AI, diverse digital resources, teacher communities, software and AI literacy education, and expanded learning spaces. Despite these promising trends, challenges remain, such as addressing the learning gap, formulating clear guidelines for student data, handling ethical concerns regarding AI, enhancing teacher competencies, and providing socio-emotional support. In conclusion, Korea's trajectory in ICT in education underscores the significance of centralized efforts and a systemic vision to transform the teaching and learning environment through digital technology.

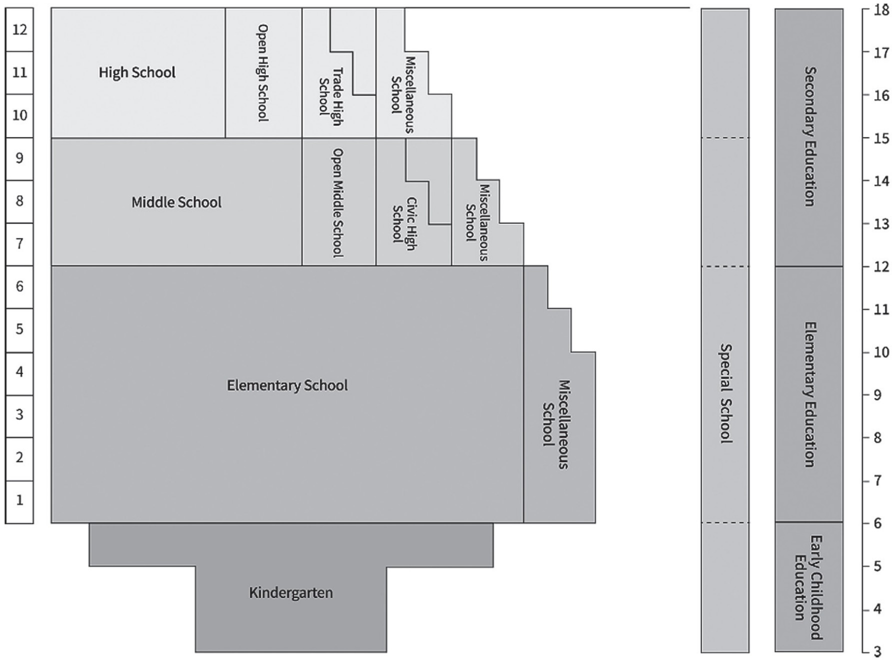
Keywords: Master Plan for ICT in Education, digital learning, digital textbooks, artificial intelligence

Introduction

Embracing the era of Digital Transformation (DX), Korea, as a leading digital-competitive nation, has been making relentless efforts to leverage digital technologies in education. The country's aspiration is to create an all-encompassing digital learning ecosystem for every member of the K-12 school community. Before delving into the specific elements of digital learning in Korea, it is essential to understand the structure of its schooling system. As depicted in Figure 1, the schooling system in Korea entails early childhood education for ages 3 to 6, followed by six years of compulsory education in elementary school for ages 7 to 12. Subsequently, students undergo three years of compulsory education in middle school at ages 13 to 15. Finally, the K-12 curriculum concludes with another three years of education in high school for ages 16 to 18. Correspondingly, the ISCED levels align with this system, where kindergarten corresponds to ISCED level 0, elementary school to level 1, middle school to level 2, and high school to level 3.

Examining the status of digital learning and its infrastructure, the majority of K-12 schools in Korea are currently in the second stage of their digital transformation journey where schools reorganize and optimize educational activities by using various digital tools for teaching and learning. This chapter aims to explore the trends and issues in digital learning in Korea as it progresses towards the third stage, Digital Transformation, which is marked by innovative and disruptive changes in education to transform teaching and learning environments with digital technology. To accomplish this, this chapter first examines the contexts of digital learning and its infrastructure, identifying five key features of digital learning based on this analysis. Subsequently, the chapter highlights the trends and issues in digital learning, building upon the insights gained from the earlier sections.

Figure 1 Schooling System in South Korea



The Status of Digital Learning

Contexts of digital learning

Digital learning policies

The Ministry of Education (MOE) spearheads the formulation of key policies concerning nationwide digital learning, supported by a decentralized implementation structure. The execution of these policies is entrusted to 17 Metropolitan and Provincial Offices of Education (MPOE) and relevant agencies, which undertake state-wide policy actions tailored to the specific needs of local communities and districts. The MOE plays a pivotal role in establishing a long-term national trajectory for digital learning through a diverse array of initiatives. Within this context, this section presents three significant ongoing initiatives in the domain of digital learning: (a) the 6th-phase Master Plan for ICT in Education (Ministry of Education [MOE], 2019), (b) the 2022 Revised National Curriculum (MOE, 2022e), and (c) the Digital-based Educational Innovation Plan (MOE, 2023a).

The 6th-phase Master Plan for ICT in Education (2019-2023)

In a systematic endeavor to advance ICT in education, the Korean government has enacted a legal mandate for the periodic formulation and execution of the Master Plan for ICT in Education every five years since 1996. The 6th-phase Master Plan for ICT in Education (6th MP) was implemented between 2019 and 2023, guided by the overarching vision of "Creating the Environment for People-Centered Intelligent Future Education." By aligning with diverse socio-cultural, economic, and technological transformations within society, the 6th MP aimed to facilitate a paradigm shift in education towards a more human-centered approach, characterized by the integration of intelligent technology (MOE, 2019). To realize its vision, the 6th MP outlined four primary objectives:

- *Future*: Creating a future-oriented ICT environment for realizing future dreams
- *Sustainable*: Innovating ICT in education for improving continuity between elementary, secondary, and tertiary education
- *Personalized*: Providing customized educational service using ICT to create equal opportunities for learning
- *Sharing*: Establishing digital infrastructure to promote communication and the sharing of educational information

The government's dedication to fostering an innovative educational landscape through ICT integration is evident in its pursuit of a more inclusive and intelligent future in education. Table 1 outlines 13 significant policy actions aimed at achieving these objectives. Among these actions, three main tasks from the 2022 plan (Educational Safety Information Bureau, 2022) hold particular importance for the future of digital learning in K-12 schools. The first action, "Establishing an ICT convergence teaching and learning support system," places emphasis on personalized education for students through digital textbooks and AI-based mathematics and English-speaking practice systems. Additionally, it facilitates teacher support through the comprehensive platform "ITDA," enabling the creation and sharing of teaching materials. The fourth action, "Establishing a future classroom where imagination becomes a reality," strives to enhance the digital infrastructure of elementary and secondary schools. This includes implementing wireless networks in all learning spaces and expanding ICT education classes, creating an environment conducive to imaginative and interactive learning experiences. The 12th action, "Integrating digital infrastructure for educational information," aims to transition educational information resources to the 4th generation Intelligent NICE, a public cloud for education information and management. This step ensures efficient access to educational information, fostering a technologically advanced learning environment.

Table 1 Specific Policy Areas and Actions in the 6th-phase Master Plan for ICT in Education (2019-2023)

Policy Area	Policy actions
I. Creating a future-oriented smart education environment	1. Establishing an ICT convergence teaching and learning support system 2. Supporting the construction of an intelligent academic and research ecosystem 3. Reinforcing digital capabilities to respond to future changes in society 4. Establishing a future classroom where imagination becomes a reality
II. Establishing sustainable ICT in education innovation	5. Expanding online learning to consider the life-cycle of education 6. Reinforcing lifelong learning and career and job information management systems 7. Enhancing educational administration services to increase work efficiency
III. Realizing customized educational services through ICT	8. Reinforcing equal welfare services based on informatization 9. Promoting the opening of customized educational information based on big data 10. Establishing a safe operating system for each field of education information
IV. Establishing a shared educational information digital infrastructure	11. Reinforcing channels for public policy communication 12. Integrating digital infrastructure for educational information 13. Expanding overseas information through exchange and cooperation

Note. Adopted from KERIS, 2021.

The 2022 Revised National Curriculum

The 2022 Revised National Curriculum represents yet another pivotal nationwide policy significantly shaping the future landscape of digital learning in Korea. Guided by the overarching vision of nurturing "An autonomous person with inclusiveness and creativity," the 2022 Revised National Curriculum seeks to cultivate diverse and self-directed education programs tailored to the unique characteristics of individual students. Officially released by the MOE in 2022, the Revised National Curriculum is slated for gradual expansion, culminating in full implementation by 2025. This comprehensive curriculum outlines essential human traits and core competencies that future education endeavors to instill, while delineating educational objectives to be achieved across various school levels.

The High School Credit System stands out as a key initiative within the framework of the 2022 revised curriculum, leveraging digital technology to foster flexible learning. This system empowers students to exercise choice in selecting subjects based on their interests and academic aptitude. By meeting specific criteria for each subject, students can accumulate credits, ultimately leading to graduation (MOE, 2021a). However, a foreseeable challenge accompanying the implementation of this innovative system revolves around instances wherein individual schools encounter difficulties in securing qualified teachers to conduct certain courses or when there is insufficient student interest, potentially compromising the feasibility of course offerings. In response to this issue, a prospective solution has been proposed in the form of the "Online Joint Curriculum." This proposal aims to promote collaboration among multiple high schools, thereby facilitating the collective provision of online courses to students from diverse schools. In support of the Online Joint Curriculum, the ClassOn platform (https://edu.classon.kr) operates as an online digital learning platform, enabling real-time interactive online classes. By integrating these cutting-edge initiatives, Korea's educational landscape continues to evolve, offering students more personalized learning experiences and overcoming traditional constraints associated with course availability and geographical boundaries.

Moreover, the 2022 Revised National Curriculum places significant emphasis on "Digital-Based Innovation in Teaching and Learning" as a key priority

(MOE, 2021d). This important initiative strives to create versatile and pioneering digital learning environments that seamlessly integrate both online and offline learning experiences. To support the successful implementation of digital learning innovations in schools, Table 2 outlines a range of curricula and operational guidelines within the framework of the 2022 Revised National Curriculum. The table demonstrates that the 2022 revised curriculum places digital learning at the forefront, playing a pivotal role in realizing student-centered personalized learning at the national level. Through this strategic integration of technology, the curriculum seeks to foster dynamic and tailored educational experiences that empower each student to thrive in their learning journey.

Table 2 Digital-Based Innovation in Teaching and Learning in the 2022 Revised National Curriculum

Curriculum	Teaching & Learning Assessment	Implementation Support
· Development of General guidelines for the curriculum that integrates online and offline learning · Provision of various distance learning types for the curriculum · Online and offline learning and an online joint curriculum that considers community and school contexts	· Development of various distance learning models and fair assessment criteria · Use of big data and AI for personalized learning, teaching, and assessment · Enhancement of online assessment and process-centered evaluation in distance learning · Enhancing assessment for the development of creativity, critical thinking, etc.	· The operation of attendance and evaluation using the learning management system (LMS) · Development of various types of learning content for different types of distance learning · Development of various distance learning, teaching, and assessment models · Supporting the enhancement of teacher competence in distance learning

Note. Adopted from MOE, 2021d.

The Digital-Based Educational Innovation Plan

The Digital-Based Educational Innovation Plan (MOE, 2023a), unveiled in 2023, stands as a comprehensive nationwide strategy formulated on the foundations of the two aforementioned policies. Guided by the overarching vision of "Realizing Customized Education for All," this plan caters to the unique competencies and learning pace of individual students, harnessing the transformative potential of digital technology. At its core, the plan seeks to "restore the essence of education" by focusing on two specific directions. The first direction involves fortifying concept-focused and problem-solving-oriented education to cultivate essential human skills such as creativity, critical thinking, and collaboration, which remain irreplaceable by AI. In this regard, the plan aims to equip students with abilities that distinguish them as individuals and foster their adaptability in an ever-evolving world. The second direction aims to establish a personalized education system that aligns with students' distinct learning goals, capabilities, and pace while nurturing meaningful teacher-student connections.

Central to achieving this vision of digital-based personalized learning is the AI Digital Textbook project, which plays a pivotal role in supporting the plan's objectives. Beyond acting as a personalized tutor, the AI textbook offers a diverse array of learning options, including multimedia content, virtual reality (VR), augmented reality (AR), and more. This dynamic integration enables students to pursue their learning seamlessly, transcending the confines of time and space. Learners can grasp fundamental concepts at their own pace through AI digital textbooks outside of school, while in the classroom, they actively participate in discussions and engage in project-based learning alongside their peers, applying their knowledge to real-world problem-solving scenarios.

Under this plan, teachers are encouraged to design and implement diverse lessons and assessments using digital technologies. The online platform, Knowledge Spring (https://educator.edunet.net/), serves as a valuable space where teachers can exchange knowledge, ideas and resources, enhancing their digital competence. Furthermore, as members of the TOUCH (Teachers who Upgrade Class with High-tech) group, teachers can actively engage in boot camp-style training programs, both online and offline, to collaboratively share AI-integrated instructional methods with fellow teachers.

Digital learning implementation in K-12 schools

Digital learning has become fully integrated into South Korea's education system, spanning across all school levels and learning domains. Schools and students have access to a variety of nation-wide online learning systems, such as e-Hakseupteo, EBS Online Class, and AI Digital Textbooks. These platforms provide digital learning content across a wide array of subjects, accommodating students from various grades and needs. The public online learning services such as e-Hakseupteo and EBS Online Class provide digital learning content in various learning areas for all grades of elementary, middle, and high school. In detail, e-Hakseupteo is being operated for elementary and middle school students, while EBS Online Class is for all school levels. This section presents three representative platforms for digital learning that have been actively used by K-12 students.

Firstly, e-Hakseupteo (https://cls.edunet.net/) is a public online learning service specifically designed for elementary and middle school students. The main objectives are to enhance the quality of public education and narrow educational gaps by providing quality online resources for teaching and learning. Before the COVID-19 pandemic, e-Hakseupteo served as a platform offering diverse content for supplementary after-school classes. However, with the advent of the pandemic, e-Hakseupteo evolved into a prominent online learning platform that effectively supports distance learning. Within "e-Hakseupteo," students have access to the individual learning history management, enabling them to view content lists, track their progress, and monitor assessment statuses to facilitate self-directed learning. Moreover, the platform provides an online classroom feature, empowering teachers to create virtual classrooms within the platform. In these virtual classrooms, teachers can organize content for students to study and assign various tasks and activities.

Secondly, EBS (Educational Broadcasting System) plays a significant role in lifelong learning and public education, offering valuable educational broadcasts that complement school education. EBS operates two prominent platforms: "Online Class" and "EBS Elementary, Middle, and High School Sites." In February 2020, EBS launched Online Class (https://www.ebsoc.co.kr/) to support public education and minimize learning gaps. This comprehensive platform provides not only a Learning Management System (LMS), but also features like interactive video classes, enabling two-way communication between students and educators. EBS Elementary, Middle, and High School Sites (https://www.ebs.co.kr/) predominantly offer level-specific learning content, covering a broad range from kindergarten to high school. The content is categorized into basic, fundamental, and advanced levels, catering to students' individual learning abilities. To further personalize learning experiences, AI Danchoo by EBS provides tailored learning services, allowing students to set their preferred learning levels. The primary services of AI Danchoo encompass seven key features: AI problem recommendation, test paper creation, AI course recommendation, problem searching, pre-learning diagnosis, and a mathematics MAP service. These AI-driven features empower students to access targeted learning materials and support their academic progress.

Finally, the AI Digital Textbook (https://dtbook.edunet.net/) stands as the latest initiative in elevating digital learning experiences through intelligent technology. Digital textbooks were introduced to complement printed textbooks, to enhance classroom teaching, and to support self-directed learning. In 2023, the MOE unveiled the AI Digital Textbooks as an integral component of the "Digital-Based Educational Innovation Plan," aligning with the overarching vision of personalized education for all (MOE, 2023a). The current features of the AI Digital Textbooks encompass personalized subject learning and AI tutoring (Ahn & Cha, 2023). Students can access personalized learning concepts for each subject, assessment questions, corresponding learning materials, and the results of their assessments. Additionally, AI tutors offer an array of functions, including personalized learning material recommendations, learning data and activity analysis, question and answer services, and more. For specific subjects, the AI Digital Textbooks are designed to leverage ITS (Intelligent Tutoring System) functions in Mathematics to support personalized learning, utilize voice recognition to enhance English listening and speaking practice, and provide enriching coding education experiences and practical activities in Information Education. The introduction of AI Digital Textbooks is planned for gradual implementation, initially targeting selected grades in Mathematics, English, and Information Education from 2025 onwards. This strategic approach ensures a well-structured integration of advanced AI technology into the educational landscape, fostering tailored and effective learning experiences for students in key subjects.

Digital learning during the COVID-19 pandemic

The COVID-19 pandemic has instigated substantial disruptions across various sectors in the country, encompassing social, economic, political, and educational realms. While the pandemic has resulted in adverse outcomes, such as learning disparities and diminished social-emotional aptitude among students, it has also propelled positive transformations toward digital learning in schools. Given the suspension of school openings nationwide due to the pandemic, online remote learning emerged as the sole feasible means to sustain educational provisions to students. Consequently, from April 9 to 20 in 2020, all school students throughout the country commenced their learning journeys via online courses. This section explores the acceleration of digital learning during the COVID-19 pandemic in Korea, focusing on four key aspects: a) technology support for digital learning, b) policy support for digital learning, c) advancement of teachers' digital competence, and d) implementation of blended learning approaches.

Technology support for digital learning

The nationwide implementation of online remote learning in response to the COVID-19 pandemic has spurred significant advancements in technology support for digital learning. The Ministry of Education (MOE) undertook initiatives to enhance digital learning platforms and learning management systems (LMS) while ensuring widespread access through the comprehensive distribution of wireless networks and smart devices to all schools. Following the outbreak of COVID-19, the MOE introduced public LMS platforms, namely the “E-learning Site” operated by the Korea Educational Research Information Service (KERIS) and “The EBS Online Class,” operated by EBS, which is capable of accommodating up to 3 million users daily (MOE, 2022b).

To bridge the digital divide and ensure equitable access to digital learning, the MOE distributed smart devices to students and facilitated the establishment of wireless networks in all schools. As of March 2022, wireless networks were installed in 386,000 learning spaces across elementary, middle, and high schools, and 250,000 devices were upgraded to the latest laptops, desktops, and tablets (MOE, 2022b). Additionally, during the second semester of 2021, 180,000 smart devices were allocated to students (MOE, 2022b), and subsequently, each MPOE has actively promoted a project to provide one smart device per student. These collective efforts have substantially improved Korea's digital learning landscape, which undoubtedly augurs well for the future of digital education in the country.

Policy support for digital learning

To effectively and systematically implement quality digital learning during the pandemic, the Ministry of Education has laid a robust foundation for nationwide digital learning initiatives. One of these significant efforts is the formulation of the "Operation Standards for Distance Learning" (MOE, 2020a). These standards delineate the concept of distance learning, categorizing it into three distinct types as shown in Figure 2: a) real-time interactive learning, b) content-centered learning, and c) task-centered learning. The first type involves conducting classes with real-time interaction, wherein teachers engage with students through video conferencing tools or social network services (SNSs). The second type encompasses content-based online classes, wherein teachers either create the content themselves or utilize various resources from national e-learning platforms such as EBS, e-Hakseupteo, and digital textbooks. The third type pertains to assignment-based online classes, where teachers assign projects and homework for students to submit via a LMS, necessitating students to demonstrate self-directed learning skills to complete the assignments. Since each of these three types of online classes presents distinct strengths and weaknesses, the MOE suggested that schools should adopt the most suitable approach based on their specific contexts and student needs.

Figure 2 Three Types of Online Classes during COVID-19

Note. Adopted from MOE, 2020a.

Another crucial endeavor is the enactment of the "Framework Act on the Promotion of Digital-Based Distance Education" (promulgated on September 24, 2021, and effective from March 25, 2022) (MOE, 2021c). The prime aim of this legislation is to elevate the quality of distance education and facilitate its systematic implementation (MOE, 2021c). This law furnishes a detailed legal framework encompassing fundamental principles of distance education, content quality management, operational standards, and the designation and functioning of specialized institutions. Subsequently, this legislation formed the legal basis for the "Operation Standards of Distance Classes for Elementary, Secondary, and Specialized Education" (MOE, 2022a). Collectively, these foundational initiatives through policy and legal actions, established in response to the pandemic, have been instrumental in setting digital education as the new norm nationwide.

Advancement of teachers' digital competence

The success of digital learning during the pandemic owes much to the dedicated efforts of teachers who adeptly designed and implemented remote online learning with digital technology. With the establishment of online platforms and comprehensive teacher training programs, both pre-service and in-service educators honed their digital competencies to ensure seamless online learning experiences. The abrupt onset of COVID-19 presented an unprecedented challenge, necessitating teachers' immediate adaptation to online teaching without adequate preparation. In response to these challenges, the MOE proactively established online teacher communities such as "the Community of 10,000 Representative Teachers," "School On," and "the Knowledge Spring" (MOE, 2022b). These communities provided invaluable spaces for teachers to share information, collaborate on solving digital learning-related issues, and forge connections with various experts in the education domain (MOE, 2022b).

As the pandemic persisted, the MOE took an innovative step by curating high-quality content from these online communities, culminating in the creation of a dedicated online platform for teachers known as ITDA (the ICT-based Teacher Development Assistance platform) (https://itda.edunet.net/). ITDA emerged as a comprehensive resource hub, offering teachers a diverse array of tools to enhance their teaching skills and deliver effective distance learning. Serving as an integrated platform, ITDA empowers teachers to efficiently search for, collect, re-organize, produce, share, and communicate a wide range of educational content suitable for their teaching and assessment needs.

In addition, the MOE supported the professional development of both in-service and pre-service teachers, particularly for enhancing their digital competencies. In 2020, the “Center of Future Education” was inaugurated with the primary objective of fostering digital and future education skills among pre-service teachers (MOE, 2021b). Across the nation, 28 Centers of Future Education were established within the National University of Education and College of Education (MOE, 2022b). These centers boast state-of-the-art facilities, including distance learning simulation and online content production rooms, offering pre-service teachers’ opportunities to acquire hands-on knowledge and skills essential for digital teaching. Through activities such as creating digital teaching materials, engaging in various digital learning activities, and utilizing digital learning platforms, pre-service teachers are expected to be well-equipped to effectively employ digital teaching methods in schools (MOE, 2021b). In addition, the MOE also facilitated systematic training programs for in-service teachers. In response to the pandemic, traditional face-to-face group training for in-service teachers was promptly transitioned to interactive online training (KERIS, 2021). These initiatives aimed at elevating teachers' digital competencies proved instrumental in delivering quality remote learning experiences to students during the challenging period of the pandemic.

Implementation of blended learning approaches

In response to the COVID-19 pandemic, the MOE took proactive measures to foster blended learning environments by proposing a range of teaching models and methods. One notable initiative was the distribution of “The Handbook for Curriculum Operation in Response to COVID-19” (MOE, 2020b), which played a pivotal role in this movement. The handbook served as a comprehensive resource, offering practical examples of blended learning in practice tailored to each grade level and subject area. Emphasizing flexibility and adaptability, the MOE encouraged schools to freely modify and tailor the handbook to suit the specific needs and characteristics of their students. Within the handbook, various blended learning models are introduced, including real-time interactive learning, content-centered learning, and task-centered learning. Moreover, the document presents detailed lesson plans and related activities based on various blended learning models. Importantly, the handbook provides recommendations for utilizing various tools and platforms, such as Zoom, EBS Online Class, QuizN, and others, that are well-suited for specific subject areas. This proactive approach aimed to empower teachers with practical guidance, ensuring seamless implementation of blended learning strategies to meet the evolving educational needs during the pandemic.

Digital learning infrastructure

Since the inception of the First Master Plan for ICT in Education in 1996, Korea has been steadily establishing and enhancing its digital infrastructure for teaching and learning. The first MP played a pivotal role in laying the foundation for building the basic ICT infrastructure in schools. With the advent of the COVID-19 pandemic, there has been a remarkable surge in progress within the ICT infrastructure to effectively support online digital learning in schools. This section examines the digital learning infrastructures in Korean schools, through the lens of the six elements proposed by Fox et al. (2021).

Leadership and budget

To ensure the successful and equitable implementation of digital learning nationwide, the government has established and executed the "Master Plan for ICT in Education" every five years. As seen in Table 3, the 6th-Phase Master Plan for ICT in Education (6th MP) spanning from 2019 to 2023 received budget allocations aligning with its overarching goals and specific policy areas (KERIS, 2022). Notably, in 2020, the MOE budget experienced an increase compared to 2019 and 2021. This rise was primarily attributed to investments made by the MOE and the Metropolitan and Provincial Offices of Education (MPOE) in establishing wireless infrastructure, enabling elementary and middle school students to access online education seamlessly.

Furthermore, in 2021, a substantial budget increase was allocated for the "Creating a future-oriented smart education environment" (see Table 4). This increase aimed to expand the provision of smart devices to students while also enhancing content, information infrastructure, and educational administrative service systems. These allocations were directed towards realizing two major areas within the 6th MP: Policy area 3 - Realizing customized educational services through ICT, and Policy area 4 -Establishing a shared educational information digital infrastructure. Such strategic funding allocations demonstrate the government's commitment to advancing digital learning and fostering a technologically enabled educational ecosystem.

Table 3 Budgets for ICT in Education by Organization Type (unit: Million KRW)

Organization	2019	2020	2021	2022
MOE	227,499	958,324	419,904	383,363
MPOE	525,635	503,117	1,165,988	1,096,556
Affiliated organizations	6,994	6,358	7,856	8,700
Relevant organizations	46,597	48,336	57,191	69,501
Total	807,725	1,516,135	1,650,939	1,557,670

Note. Adopted from KERIS, 2022.

Table 4 Budgets for ICT in Education by Policy Area (unit: Million KRW)

Policy area	2019	2020	2021	2022
1. Creating a future-oriented smart education environment	286,832	1,017,726	1,102,636	928,843
2. Establishing sustainable ICT in education innovation	388,242	329,025	399,100	450,289
3. Realizing customized educational services through ICT	98,043	115,325	112,009	131,454
4. Establishing a shared educational information digital infrastructure	34,608	54,059	37,194	47,084
Total	807,725	1,516,135	1,650,939	1,557,670

Note. Adopted from KERIS, 2022.

Course design and delivery

The Korean government has taken significant strides to harness the potential of digital learning, with a keen focus on providing equal learning opportunities to students at all levels of education. Table 5 provides an overview of digital learning platforms specifically tailored to a diverse range of student needs. These platforms address the requirements of students with disabilities, student athletes facing challenges in regular attendance, students from multicultural backgrounds, and individuals who had previously dropped out of school or missed secondary education opportunities. The implementation of these digital learning platforms reflects the government's commitment to promoting inclusive access to education and offering flexible learning experiences that cater to the unique needs and characteristics of each student.

One such platform is "Online Supplementary Courses” (https://onlineschool.or.kr), which operates both "Supplementary learning" and "Unopened courses" programs. The "Supplementary learning" program ensures that students have access to learning opportunities in subjects they may have missed due to transfers or other reasons. On the other hand, the "Unopened courses" program allows students the opportunity to choose subjects that may be challenging to offer within their school due to internal constraints. As of 2022, this platform offered online courses in 163 subjects (75 for middle schools and 88 for high schools). The availability of diverse subjects on this platform empowers students to pursue their academic interests and fill any learning gaps they may have encountered, thereby fostering a more inclusive and enriched educational experience.

Secondly, "e-School” (https://hs.e-school.or.kr) has been developed specifically to cater to the needs of student-athletes who may face absences due to their sports-related commitments. The primary objective of this platform is to safeguard the learning rights of student-athletes and provide supplementary learning support for students with inadequate academic achievements. The main programs offered by e-School include the "Regular Semester Curriculum" and the "Run-up Curriculum." They encompass a wide range of subjects, incorporating both regular curriculum content and specialized material tailored to meet the specific needs of student-athletes.

Thirdly, "Open Middle and High Schools" (https://www.cyber.ms.kr, https://www.cyber.hs.kr) represent a unique educational opportunity aimed at serving a diverse student population, ranging from teenagers to individuals over 80 years old. These online schools are committed to broadening access to secondary education and facilitating students' acquisition of academic qualifications. Their approach revolves around a blended education model that can be personalized to cater to the unique needs of individual learners. A noteworthy aspect of these schools is the consideration of learner characteristics, with over-60-year-olds constituting 58.3% of the student population (KERIS, 2022). The learning methods employed consist of 90% distance classes and 10% offline classes. Additionally, microlearning has been integrated into the instructional approach, which includes topic-centered video content, activity-centered learning materials, and various difficulty levels of formative assessments.

Fourthly, online learning platforms cater to the needs of students with disabilities, ensuring inclusive educational opportunities. "School for You" (https://www.s4u.kr) offers online education using diverse video content, VR, and AR platforms specifically designed for elementary and middle school students with health impairments and students in hospital schools. Its main objective is to maintain academic continuity for students facing health-related challenges, thereby facilitating their participation in regular school activities. Additionally, "Open Learning Ground" (https://class.nise.go.kr) serves as an integrated platform that supports teachers, students, and parents in the field of special education. This platform provides both synchronous and asynchronous digital teaching and learning experiences by offering live video classes and personalized content on various topics.

Lastly, the "National Center for Multi-Culture Education" (http://www.edu4mc.or.kr/) plays a crucial role in ensuring the educational rights of multicultural students. This platform aims to support the integration of multicultural students into the public education system, and offers various online educational resources to aid their adaptation to school life. A key feature of the platform is the provision of "Bilingual textbooks" and "Curriculum aid materials" to facilitate distance learning for multicultural students. The "Bilingual textbooks" encompass languages such as Russian, Cambodian, Thai, Mongolian, and Indonesian, providing students with the opportunity to learn their parents' native language and culture. The "Curriculum aid materials" offer "Self-learning vocabulary in the curriculum," helping students grasp curriculum-related vocabulary more effectively and enhancing their basic academic skills.

Table 5 Digital Learning Platforms Tailored to Various Student Groups and Needs

Student Groups	Digital Learning Platforms	URLs
Transfer Students	Online Supplementary Courses	https://hs.onlineschool.or.kr/main.do
Student-Athletes	e-School	https://hs.e-school.or.kr/main.do
School drop-outs and adult learners	Open Secondary Schools	https://www.cyber.ms.kr/portal/index.do (middle school) https://www.cyber.hs.kr/portal/index.do (high school)
Students with Disabilities & hospital schools	School for You	https://www.s4u.kr/
Students with Special Educational Needs	Open Learning Ground	https://class.nise.go.kr/hre/cm/mcom/pmco000b00.do
	Eduable	https://www.nise.go.kr/main.do?s=eduable
	Online Learning Room for Students with Disabilities	https://www.nise.go.kr/jsp/onlineedu/index.jsp
Multicultural Students	National Center for Multi-Culture Education	https://www.edu4mc.or.kr/

Student success in digital learning

This section examines students' success in digital learning concerning (a) their access to digital devices and (b) digital learning competencies. In pursuit of promoting students' digital learning experiences, Korea has taken proactive measures to support the distribution of digital devices, as demonstrated in Table 6. Notably, as of 2022, elementary schools exhibited the highest distribution of digital devices, with 6,359 schools benefiting from this initiative (KERIS, 2022). On a per-user basis, the distribution to students accounts for a significant proportion at 60.97%. This noteworthy progress in providing digital devices to students was made possible by a substantial increase in the budget allocated for the "Creating a future-oriented smart education environment" in 2021 under the 6th MP.

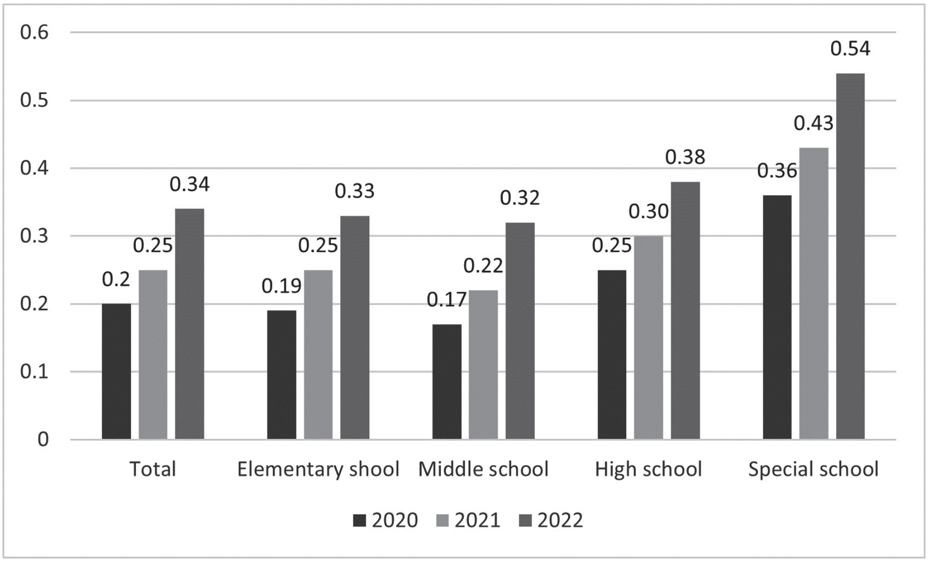
Table 6 Distribution of Digital Devices by School Level and User Type

Category	Total number of schools	Total number of units per user				
		Total	Students		Teachers	
			Units	%	Units	%
Total	12,209	2,954,631	1,801,379	60.97	891,373	30.17
Elementary school	6,359	1,372,307	876,197	63.85	367,013	26.74
Middle school	3,278	727,993	429,403	58.98	234,979	32.28
High school	2,379	814,425	480,406	58.99	270,593	33.23
Special school	193	39,906	15,373	38.52	18,788	47.08

Note. 1. * Number of units for other school staff is not indicated in this table.
2. Adopted from KERIS, 2022.

Examining the data on the number of digital devices per student in the past three years, as depicted in Figure 3, a consistent upward trend is evident. In 2020, the ratio stood at 0.20 devices per student, which then increased to 0.25 devices in 2021. By 2022, this number had further risen to 0.34 devices per student. Such advancements reflect the concerted efforts and commitment of the educational authorities to equip students with the necessary digital resources, ensuring enhanced access for successful digital learning experiences.

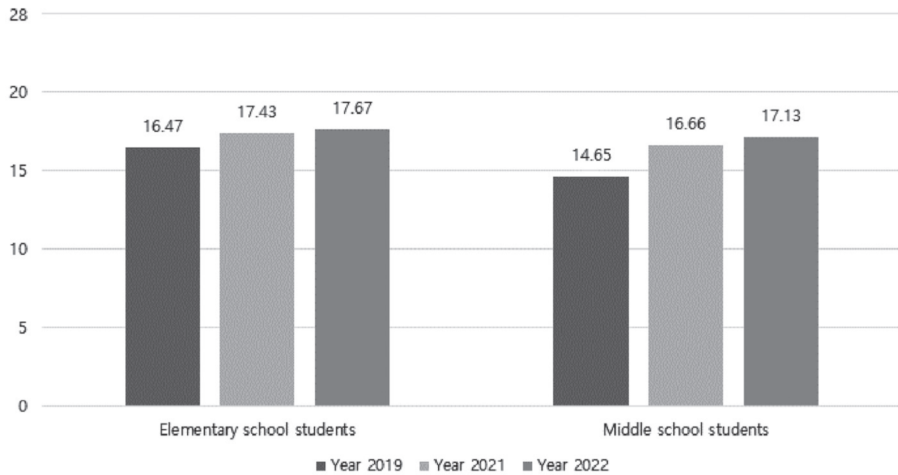
Figure 3 Number of Students per Digital Device in 2020-2022



Note. Adopted from KERIS, 2022.

Secondly, students' digital literacy skills have been showing gradual improvement with the MOE's steadfast support for enhancing digital learning in schools. As shown in Figure 4, the level of digital literacy skills has been measured annually from 2019 to 2022 (Yi et al., 2022). Focusing on elementary school students, their digital literacy score witnessed a positive trajectory. In 2019, the total score was 16.47 out of 28, which climbed to 17.43 in 2021 and further increased to 17.67 in 2022. Middle school students exhibited a similar trend of improvement. Their digital literacy score was 14.65 in 2019, showing an increase to 16.66 in 2021, and reaching 17.13 in 2022. These encouraging trends in digital literacy skills highlight the tangible benefits of the MOE's dedicated efforts in bolstering digital learning support. As students' digital competencies continue to improve, the foundation for successful and effective digital learning experiences becomes stronger, positioning learners for a future that embraces the opportunities of a digitally connected world.

Figure 4 Comparison of Student Digital Literacy Levels by Year 2019-2022



Note. 1. Year 2020 data is missing due to COVID-19

2. Adopted from Yi et al., 2022.

Evaluation and analytics

To enhance teachers' evaluation expertise and streamline the evaluation process, two essential platforms are currently in use: a) the Student Evaluation Support Portal and b) NEIS (the National Education Information System). Firstly, the Student Evaluation Support Portal (https://stas.moe.go.kr) offers a valuable search service that grants access to high-quality evaluation tools and resources categorized by school grade and subject. This platform ensures the availability of reliable evaluation materials sourced from the MOE, MPOE, and reputable research institutions. Additionally, the portal promotes collaboration among teachers by offering a materials repository where teachers can share their evaluation resources, fostering a sense of community and knowledge-sharing among teaching professionals. Furthermore, the portal provides a wealth of supplementary materials and training videos to enhance teachers' proficiency in conducting evaluations effectively.

Secondly, NEIS (https://www.neis.go.kr) serves as a comprehensive platform designed to facilitate efficient educational administration across all schools in South Korea. Since its launch in 2002, NEIS has been actively utilized and has continuously evolved to meet the evolving needs of schools. Its core features empower schools and educational organizations to carry out administrative tasks based on the data stored in NEIS, while also ensuring that the public can access valuable educational information. In 2023, the introduction of the 4th generation intelligent NEIS service marked a significant advancement, incorporating various cutting-edge technologies and transforming into a forward-thinking information system. This new iteration promotes future-oriented education by encouraging active participation from students and parents, streamlining administrative processes for schools and educational offices, and fostering collaboration with government agencies and private sectors. Since its inception, NEIS has played a vital role in facilitating seamless educational administrative tasks and contributing to the digital learning innovation in South Korea.

Teacher and staff professional development

Teachers play a critical role in providing meaningful digital learning experiences to students. To equip them with the necessary digital competencies, several teacher professional development (TPD) programs have been introduced. This section presents four representative initiatives that aim to enhance teachers' digital competencies through systematic TPD courses and programs: a) The KERIS Education Training Institute and Knowledge Spring, b) Distance Education Training Support Center, c) Learning Nuri Center, and d) AI Convergence Education Major.

The KERIS Education Training Institute (https://www.cet.keris.or.kr) serves as a central hub for providing TPD courses to teachers. Over the past five years (KERIS, 2022), the institute has offered various courses focusing on three main areas, as summarized in Table 7. In particular, the "Knowledge

Spring" (https://educator.edunet.net/) platform was specifically developed in response to the paradigm shift from face-to-face to distance training due to the impact of COVID-19. This platform facilitates synchronous sharing of essential knowledge on digital learning where teachers can create and offer courses, sharing their expertise with other teachers. Moreover, teachers have the flexibility to choose and enroll in customized courses based on their specific preferences and needs.

Table 7 Teacher Training by the KERIS Comprehensive Education and Training Institute

Areas		2019		2020		2021		2022.6	
		NC*	NT*	NC*	NT*	NC*	NT*	NC*	NT*
Enhancing ICT competencies in elementary and secondary education	SW and AI education	4	2,475	6	1,309	5	531	3	298
	Digital textbooks	11	1,344	3	229	-	-	80	1,436
ICT in education-based training	Enhancing NEIS competency	2	122	1	65	1	68	-	-
	Prevention of cyber violence and Information and Communication ethics	1	170	1	417	1	718	-	-
	Copyrights related to education	1	67	1	48	2	51	-	-
Enhancing EduTech competencies	Knowledge Spring	-	-	236	1,306	1,802	10,216	1,204	7,420
	ICT utilization training	2	104	1	17	12	330	11	360

Note. 1. *NC: Number of Courses, NT: Number of trainees who completed courses

2. Adopted from KERIS, 2022.

Next, the Distance Teacher Training Support Center (https://ttc.edunet.net) aims to provide teachers with diverse and high-quality distance training content. As teachers seek to strengthen their digital competencies during the pandemic, the demand for distance training has surged. As such, the Learning Nuri Center (https://manage.study.go.kr) was launched in 2022 as an integrated teacher training platform (MOE, 2022f). The main objective is to move away from traditional passive training methods and empower teachers to actively create their learning path. Leveraging big data and AI, the platform analyzes teachers' training processes and provides personalized dashboards. Based on teachers' demands and interests, the platform also recommends tailored training courses and offers access to external courses such as K-MOOC, KOCW, TED lectures as well as a wide range of micro-learning content.

Lastly, the “AI Convergence Education Major” initiative was established in response to the growing interest in AI education. Starting in September 2020, the government collaborated with universities to establish AI convergence education majors within graduate schools, aiming to enhance teachers' AI education competencies. Currently, 42 universities across the nation offer AI convergence education programs (Lim et al., 2020). These programs cover essential topics such as educational programming, data science, computational thinking, problem-solving, instructional design, and educational data analysis. The focus on AI education underscores the government's commitment to equipping teachers with the necessary skills and knowledge to navigate the evolving digital landscape effectively.

Technology infrastructure

To establish a future-oriented educational environment based on ICT, the Korean government is diligently developing wired and wireless network infrastructures in schools nationwide (KERIS, 2022). The wired infrastructure is facilitated through the nationwide Schoolnet service, granting schools unrestricted Internet access. It also diagnoses and resolves any local area network issues within schools and addresses central equipment malfunctions to optimize performance. Regarding wireless infrastructure, between 2017 and 2020, a total of 18,255 wireless access points (APs) were deployed in 5,413 schools across the country, with 340,046 smart devices distributed (KERIS, 2022). The sudden impact of COVID-19 led to the establishment of giga-level wireless networks in schools to cope with the changing circumstances. As part of the government's New Deal project, the first phase was initiated in July 2020, creating giga-level wireless infrastructures in classrooms and replacing outdated computers for teachers. In February 2022, the second phase was implemented to establish wireless networks in 380,000 learning spaces. With the development of giga-level wireless infrastructures in all schools, it became possible to utilize immersive content such as AR and VR in classrooms.

As mentioned earlier, various platforms and infrastructures have been developed to offer effective digital learning experiences to students while supporting teachers with various teaching materials and professional development opportunities. These platforms, including "ITDA," "e-Hakseupteo," "Digital Textbooks," and "Knowledge Spring," are integrated and accessible through the "Edunet T-CLEAR" (https://www.edunet.net) site. Edunet T-CLEAR, which stands for Teacher-Curriculum, Learning Evaluation, and Activity Resources, functions as an integrated education information service managing various platforms, thereby allowing students and teachers to benefit from easy access to essential resources.

Features of digital learning

Digital learning in Korea can be summarized by five main features that highlight the country's commitment to providing equitable and innovative education. First, Korea has been establishing national-level Master Plans for ICT in Education since 1996, guiding the development of digital learning through five core values: accessibility, innovation, competency development, openness, and inclusiveness. These plans are implemented through systematic and government-led initiatives in five-year intervals, allowing for continuous progress in digital learning and effective responses to unforeseen events like the COVID-19 pandemic.

Second, there is a strong emphasis on providing diverse training opportunities to enhance teachers' competencies. Even before COVID-19, teacher training was actively conducted through face-to-face and distance learning programs. Initiatives like the “Distance Education Training Support Center” and the "Learning Nuri Center" platform aim to empower teachers to actively create learning paths for their future competencies. Furthermore, the "AI Convergence Education Graduate School Program" fosters teachers' AI competencies through varied learning approaches as well as supporting teachers to receive an academic degree in the graduate school program.

Third, Korea has developed learner-centered platforms to ensure students' right to education and accommodate diverse learning needs. With the accelerated adoption of distance education due to COVID-19, digital learning platforms have evolved to include personalized features. For instance, "AI Danchoo" provides personalized recommendations, test paper generation, and learning diagnostics for individual students. Platforms like "Online Supplementary Courses," "Open Middle and High Schools," and "School for You" cater to educationally marginalized groups and students with learning needs, ensuring equitable learning opportunities.

Fourth, AI digital textbooks have emerged as a major medium for digital learning in public education. Originally introduced in 2009 to provide multimedia learning environments beyond traditional text-based content, these textbooks have evolved into AI digital textbooks with more intelligent features. AI digital textbooks analyze learner data and offer personalized learning experiences, facilitating flipped learning and learner-centered approaches. This transformation in the education landscape is driving significant changes, promoting collaboration and application of knowledge in the classroom.

Lastly, Korea's high-speed Internet connectivity and advanced ICT infrastructure in schools play a crucial role in smoothly implementing digital learning initiatives. This robust infrastructure has fostered the development and utilization of various national-level learning services and platforms, contributing to the successful implementation and widespread adoption of digital learning across the country. Overall, these five key features demonstrate Korea's dedication to providing quality and equitable digital learning experiences for students and teachers alike, establishing the nation as a global leader in digital education.

Trends and Issues in Digital Learning

Trends in digital learning

Integrating artificial intelligence in digital learning

Korea has witnessed a notable trend of incorporating AI technology into digital teaching and learning. With the rapid advancements in AI technology coinciding with the pandemic, there has been a continuous effort to integrate AI into various digital learning platforms. For instance, EBS's AI Danchoo offers various features, such as analyzing students' performance data to recommend suitable courses. Similarly, AI digital textbooks, currently under active development, aim to provide personalized learning based on students' learning and assessment data. Edunet T-CLEAR and School for You have embraced AI technology since 2021 to foster personalized and student-centered learning approaches, further enriching their capabilities. This growing integration of AI in digital learning promises to revolutionize educational experiences and enhance learning outcomes for students.

Offering diverse digital learning resources

Korea offers a wide array of platforms dedicated to facilitating digital learning for both students and teachers. A standout feature of these platforms is the abundance of digital content available for teaching and learning purposes. For instance, the e-Hakseupteo platform offers curriculum-based learning content, foundational materials, and interactive experiential activities. Open Middle and High Schools cater to educationally marginalized groups by providing topic-centered video content and activity-oriented learning materials to help students acquire academic qualifications. For teachers, the Learning Nuri Center platform serves as a valuable resource by providing access to K-MOOC, KOCW, TED lectures, and micro-learning content. These diverse offerings ensure that educators have a wealth of materials to create engaging and effective lessons. Additionally, many of these platforms incorporate microlearning formats and recommendation systems, tailoring content to individual learners' needs and preferences. The availability of diverse digital learning resources through these platforms is revolutionizing the landscape of education in Korea, catering to the unique requirements of both students and teachers, and fostering a transformative shift in learning approaches throughout the country.

Fostering teacher communities for strengthening digital learning competencies

Teachers are now active participants in the digital learning landscape, not just as consumers but also as content creators. As they enhance their skills and prepare teaching materials, the emphasis is on fostering teachers' digital learning competencies through platforms like "Knowledge Spring," which facilitate knowledge and content sharing among educators. Additionally, platforms like "ITDA" enable teachers to create, utilize, and exchange teaching materials. These platforms promote active interaction among teachers, fostering a supportive online teacher community that helps them strengthen their digital learning competencies.

Expanding software and AI literacy education for both students and teachers

Since the announcement of the National Talent Development Policy in 2020, there has been a concerted effort to enhance software and AI education, focusing on improving students' and teachers' digital skills as well as fostering their creativity and collaborative problem-solving abilities. A strong foundation for literacy education has been established, aiming to promote SW and AI convergence education, to ample digital learning opportunities, and to bridge the digital divide. Starting in 2020, the expansion of AI education leading schools has been a priority, serving to bolster the groundwork for AI education. In 2022, significant efforts were made to develop and distribute teaching and learning materials for digital literacy education. Teachers also have the opportunity to attend training programs at the KERIS Comprehensive Education Training Institute, which consistently covers topics related to SW education, AI, and ICT integration. As training formats have shifted to online platforms, the Knowledge Spring platform offers a variety of courses related to SW and AI literacy. Some of the recently popular courses on this platform include "Innovation in Training through ChatGPT," "Application Development," and "Python Coding Education."

Expanding online learning spaces

The digital learning infrastructures examined thus far have significantly broadened the horizons of school education spaces. The imperative of digital learning became evident during COVID-19, prompting the active utilization of existing online learning platforms like e-Hakseupteo and Edunet T-CLEAR. Even with the resumption of face-to-face education in schools, these online platforms continue to facilitate teacher-student interaction and support personalized learning. Moreover, the High School Credit System, introduced in the 2022 Revised National Curriculum, leverages the ClassOn platform, enabling multiple high schools to collaborate on joint educational programs with real-time and interactive online classes. Consequently, learning experiences are no longer confined to physical school settings but extend to digital learning spaces. This empowers students to explore diverse academic subjects and chart their learning paths based on their interests and aptitudes, unrestricted by time and location constraints.

Issues in digital learning

Widened learning disparities during COVID-19

The learning gap has emerged as one of the significant challenges in Korea. As mentioned earlier in the Contexts of Digital Learning, the COVID-19 outbreak compelled all students to take full responsibility for their education, exposing various environmental and individual factors that hindered their engagement and academic progress. Consequently, disparities in academic performance among students widened significantly. According to Kye et al. (2020), approximately 79% of teachers nationwide observed a widening learning gap between students during the initial phase of COVID-19 and digital learning implementation.

To tackle this issue, the MOE has made considerable efforts to provide personalized support to individual students. The MOE is also actively expanding the distribution of one digital device per student in schools to bridge the digital divide. As of December 2022, the distribution ratio stood at 0.47 devices per person for elementary school students, 0.65 for middle school students, and 0.47 for high school students. The MOE aims to increase this ratio to 0.69 devices per person by the end of 2023 (MOE, 2023b). Furthermore, the "Comprehensive Plan to Ensure Basic Academic Skills (2023-2027)" (MOE, 2022d) was introduced to ensure basic academic skills for all students. This comprehensive plan outlines the implementation of an AI-based diagnostic assessment and personalized support system, aiming to guarantee that every student possesses essential academic competencies. By leveraging advanced technologies, the MOE is committed to addressing the learning gap and creating more equitable learning opportunities for all students.

Lack of clear guidelines on student data

Despite South Korea's progressive steps towards personalized education using AI, there remains a lack of clear standards for the secure collection and management of student learning data (Ahn & Cha, 2023). The development of the AI Digital Textbook by the MOE relies on systematic and secure data collection, management, and analysis of learners' data. However, the absence of common standards for learning data poses various challenges that must be addressed and agreed upon. Key issues include personal information security, delineating responsibilities, establishing indicators for common data set standards, and defining guidelines for data collection, transmission, and copyrights.

To ensure the safe utilization of students' learning data for educational purposes, it is essential to establish comprehensive guidelines that clearly define the collection and management system and the scope of usage and authority regarding learning data. By addressing these concerns, it is possible to safeguard the privacy and security of students' personal information while leveraging the potential of AI and data analytics to enhance personalized learning experiences. Establishing robust guidelines will not only protect students' data but also foster a conducive environment for utilizing their learning journey effectively and securely in the pursuit of better education outcomes.

Ethical issues of AI in education

The emergence of OpenAI's ChatGPT in late 2022 has reignited ethical concerns surrounding AI in education. In Korea, the controversial AI chatbot, "Lee Luda," sparked heated debates due to its use of offensive and discriminatory language targeting women and minorities. This incident brought to light the pressing need for addressing ethical issues related to AI and its impact on education. In response, the Ministry of Education (2022c) issued the "Ethical Principles of Artificial Intelligence in Education Supporting Human Growth." This comprehensive document outlines 10 detailed principles, all under the overarching concept of "AI that supports human growth," to ensure the safe and responsible use of AI in supporting learners' development in education.

Recognizing the importance of fostering students' understanding of AI's potential opportunities and risks, the Ministry of Science and ICT (MSIT) and the Korea Information Society Development Institute (KISDI) took actions by publishing AI Ethics Textbooks tailored to each school level in 2023 (KISDI, 2023). These educational materials aim to equip students with the knowledge needed to engage with AI responsibly and ethically. However, the fast-paced advancements in technology continue to pose challenges. Generative AI, exemplified by ChatGPT and Midjourney, has introduced new issues such as cheating, copyright violations, and the dissemination of false information. This highlights the necessity of constantly updating AI ethics in education to effectively address the novel opportunities and challenges presented by generative AI. Maintaining a proactive and up-to-date approach to AI ethics in education is crucial to ensure the ethical and responsible implementation of AI technologies, safeguarding the learning environment and fostering a positive and secure learning experience for all students.

Challenges in teachers' digital competency development

Despite teachers' willingness to embrace digital transformation, several challenges hinder their progress in developing digital competencies. Jeong (2023) conducted a survey of 1,000 teachers nationwide to explore the status of digital technology utilization and teachers' perceptions of digital transformation in schools. The findings revealed that teachers generally perceived themselves, their colleagues, and school administrators as receptive to digital technology (56.7%, 43.9%, and 47.7%, respectively). Moreover, 41.6% of teachers acknowledged the need for digital transformation and expressed their proactive willingness to prepare for it. This positive attitude towards digital learning is further supported by the MOE's various initiatives for in-service and pre-service teacher professional development, as discussed in the Teacher and Staff Professional Development section.

Despite these positive outlooks and improved competencies, however, teachers face significant obstacles in integrating digital technologies for teaching and learning in schools. Teachers are often burdened with various responsibilities, including high teaching load, parent and student counseling, and administrative tasks, leaving limited time for utilizing their newly acquired digital skills. Jeong's study (2023) also highlighted that the primary factor hindering teachers' acceptance and utilization of digital technology in schools is the lack of supporting environments (59.6%). This finding suggests that teachers perceive their workload and time constraints as major barriers to effectively incorporating digital technology in the classroom. Addressing this issue is crucial for digital learning to become a sustainable norm in education. Therefore, urgent attention is required to reduce teachers' workload while improving their working environment.

Insufficient socio-emotional support

In the realm of digital learning in Korea, there has been relatively little emphasis on addressing the social and emotional aspects of students' learning. In a digital learning environment where face-to-face interactions are limited, the need to support students' emotions and social interactions becomes even more crucial. Furthermore, the challenges posed by the COVID-19 pandemic have led to an increase in students experiencing the “COVID-19 blues” and “Back-to-School blues” (Sung et al., 2023). Despite this pressing issue, digital learning in South Korea has tended to prioritize cognitive and academic aspects, inadvertently neglecting the social and emotional dimensions of learning.

In recognition of this concern, the MOE responded by releasing the "Comprehensive Plan for Educational Recovery" (MOE, 2022a), aimed at nurturing socially and emotionally well-rounded individuals. Another notable initiative, the "Study of EdTech-Based Emotional Support Model for Students" (Sung et al., 2022), strives to leverage educational technology in supporting students' social and emotional development. These nationwide actions reflect Korea's dedication to bridging the gap in socio-emotional support and steering towards the holistic well-being of students in the digital learning landscape.

Conclusion

Korea has been diligently laying the groundwork for digital learning since 1996 through the systematic implementation of the Master Plan for ICT in Education, a comprehensive five-year strategy to revolutionize digital learning in schools. This strong foundation in technological infrastructure proved instrumental in handling the unforeseen challenges posed by the COVID-19 pandemic. As the country ventures into the era of the 4th Industrial Revolution, it becomes evident that significant changes are required in teaching and learning environments to harness the potential of digital and intelligent technologies, equipping students with essential 21st-century skills to excel in the global landscape. The introduction of the 2022 Revised National Curriculum, emphasizing student agency, creativity, and problem-solving skills, along with various policy initiatives like the Digital-Based Educational Innovation Plan, has supported this digital transformation.

This chapter explored the digital learning ecosystem in Korea based on Fox et al.'s (2021) six elements of digital education infrastructure. The analysis of the current digital learning infrastructure reveals the Korean government's continuous efforts to build a digital learning ecosystem that fosters meaningful and flexible learning experiences. The dominant trends in digital learning encompass integrating AI into educational practices, providing diverse digital learning resources, fostering teacher communities for digital learning practices, promoting software and AI literacy education, and expanding learning spaces to embrace digital environments. However, amidst these promising trends, schools in Korea also face several challenges related to digital learning. These issues are a result of the rapid development of digital technologies, coupled with the socio-economic changes driven by AI. The key issues include addressing the learning gap, establishing clear guidelines for student data usage, addressing ethical concerns surrounding AI in education, enhancing teachers' digital competencies, and providing sufficient socio-emotional support for students.

Yet, Korea is actively turning these challenges into opportunities for digital transformation in education. With the forthcoming 7th-phase Master Plan for ICT in Education in 2024 and the full implementation of the revised curriculum in 2025, Korea is taking significant strides towards comprehensive digital transformation. The passion for education combined with a solid technological foundation promises a transformative future ecosystem for digital learning in Korea.

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Trends and Issues of Digital Learning in Sweden

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Abstract

This chapter discusses the trends and issues surrounding digital learning in K-12 schools in Sweden. It begins with an introduction to digital transformation in education and highlights its importance, both in Sweden and also more generally. The focus then shifts specifically to K-12 schools in Sweden and examines the current status of digital learning in this context, explaining the established physical IT infrastructure and broad use of digital tools at all levels of education. The challenges of COVID-19 were a catalyst to implement more goal-oriented activities for teachers and learners. This chapter identifies several trends in digital learning, including the integration of technology into the curriculum, the use of online resources and platforms, the implementation of personalized learning approaches, testbeds, programming and generative AI. It also highlights the challenges and issues associated with digital learning, such as the need for adequate infrastructure, technical support and teacher training, ensuring digital inclusion for all students, and addressing concerns regarding data privacy and security. In conclusion, this chapter emphasizes the need for continued efforts to foster digital learning in K-12 schools in Sweden, while also addressing the associated issues. It suggests that educators and stakeholders should collaborate to provide necessary resources and support for effective digital learning implementation in the classroom.

Keywords: digital learning, digital transformation, Sweden, K-12

Introduction

Structure of the schooling system

The Swedish education system is divided into three main levels: voluntary preschool, compulsory elementary (primary) and lower secondary education, and voluntary upper secondary education[1]. Figure 1 provides a breakdown of the Swedish school system, with a fourth and fifth level concerning adult education. The school system is designed to be comprehensive and democratic, with a strong focus on individual needs and abilities.

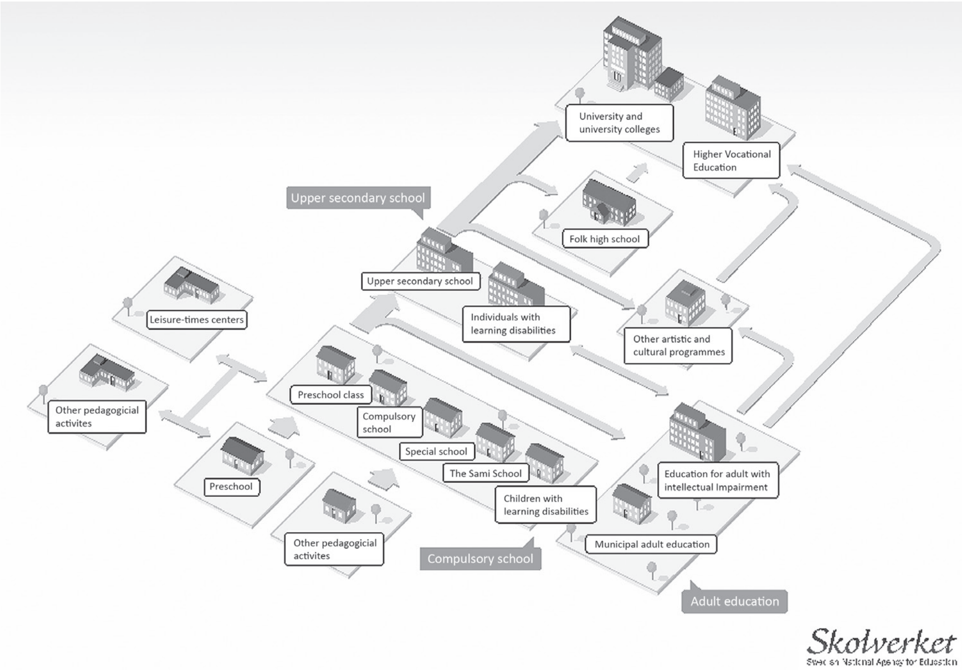
Preschool education is available for children aged 1-5 years old, but is not mandatory. However, most children in Sweden attend preschool. The preschool curriculum aims to provide a safe and stimulating environment for children to learn and develop their social, emotional, and cognitive skills.

Compulsory education (*grundskola*) in Sweden starts at the age of 7 and lasts for 9 years. However, children can start at the age of 6 with a year of voluntary pre-school that introduces them to several curriculum-related subjects. Compulsory education is divided into two stages: elementary school and lower secondary school. Elementary school lasts for 6 years, from the age of 7 to 12, while lower secondary school lasts for 3 years, from the age of 13 to 15. From year 6 and onwards, pupils are awarded grades, with final grades when graduating in year 9. The academic year is divided into one autumn and one spring term. During compulsory education, pupils receive a broad and comprehensive education in a range of subjects, including Swedish, English, Mathematics, Geography, History, Religious knowledge, Civics, Biology, Physics, Chemistry, Technology, Arts, Home Economics, Sport and Health,

1 https://utbildningsguiden.skolverket.se/languages/english-engelska/det-har-ar-den-svenska-skolan

Music, Textiles, Wood and Metalwork, and a supplementary foreign language.

Figure 1 The Swedish Education System



Note. Figure provided by the Swedish National Agency for Education.

After completing compulsory education, students can choose to continue their education at upper secondary school (gymnasieskola). Upper secondary education is not mandatory, yet most students choose to pursue it. Upper secondary education is divided into 18 national programs, each with its own specialized curriculum. Students choose a program based on their interests and future career aspirations, but grades play a significant role in admission, especially for some of the more favored programs. Upper secondary education usually lasts for 3 years and culminates in a series of final exams. These do not alone determine whether students are eligible for higher education; the composition of different programs, and their respective courses will, together with the final course grades, make up the final result on which students are assessed for further education. Table 1 presents a breakdown of the number of students and teachers in the major three levels of education (statistics from the Swedish National Agency for Education).

Table 1 A Breakdown of the Total Number of Students and Teachers in the Major Levels of Swedish Schools during the Latest School Year

School Year 2021/2022			
	Compulsory Municipal	Compulsory Independent	Upper Secondary (all forms)
Number of Schools	3,897	828	1295
Number of Students	918,569	178,207	364,431
% Female	48	50	49
% Male	52	50	51
% with a foreign background	27	29	29
Number of Teachers on duty	89,323	16,241	29,905
% Female	68	70	52
% Male	32	30	48

In Sweden, children with learning disabilities attend mandatory special school (*särskolan*) from the ages of seven to sixteen. After the mandatory part, the upper secondary school is also available, but it is optional and offers special national, individual, or special-format programs. For the Sami ethnic group, there are specialized Sami schools available for the first six years of a child's education, after which they can continue their education in regular compulsory basic schools.

Sweden also has a strong tradition of adult education (Vuxenutbildning/*komvux*), with each of the 290 municipalities providing various courses at the compulsory basic and upper secondary school levels. Adult students over the age of 18 take the same subjects and courses as younger students, but at an accelerated pace. Municipal adult education is also available for individuals with learning disabilities. Newly arrived immigrants who are 16 years of age or older have the right to receive Swedish language education through a Swedish for Immigrants (SFI) program to acquire basic Swedish skills. Additionally, pupils with foreign backgrounds also have the right to education in their native language as a primary school subject, and may work with study materials written in their native language.

The K-12 (Preschool - Post Secondary) school system in Sweden is governed by the state through various means, such as statutes, government orders, curricula, and syllabi. These documents provide direction and guidance for all aspects of education. The municipalities are tasked then with overseeing compulsory and upper secondary education, as well as adult education programs. The Swedish National Agency for Education (Skolverket) serves as the central authority responsible for overseeing the implementation, evaluation, and development of the education system through the Swedish Education Act. The K-12 system of education in Sweden is publicly financed and exempt from fees. In addition, both compulsory and upper secondary school students have the freedom to select their preferred school. For instance, a student who is passionate about music, drama, art, or a specific sport can choose to attend a school with that particular profile. In addition, students can choose also to attend an independent school operated by a non-municipal entity. However, independent schools must be approved by the National Agency for Education and must be accessible to everyone while adhering to the Swedish Education Act. Although independent schools are financially supported by public funds and receive a grant from the municipality for each pupil, they can also impose modest fees at the upper secondary school level. Independent schools often implement specific teaching methods such as Montessori or Waldorf, or can opt to provide only a select number of upper secondary programs. Approximately 3.5% of all Swedish students in compulsory basic school and upper secondary school attend independent schools.

Overall, the Swedish school system is designed to be comprehensive, egalitarian, and focused on individual needs and abilities.

Digital transformation and current stage in K-12 schools

Digital technologies are transforming, among much else in society, the way we provide teaching and learning for a sustainable future. Digital transformation (DX) is a journey of three stages (Luo & Wee, 2021): Stage I - Digitization, conversion of non-digital records to digital format, for example from printed books to digital learning material; Stage II - Digitalization, conversion of processes or interactions into digital equivalents, for example using a mathematics application on a tablet to learn multiplication and division; and Stage III - DX, innovative and disruptive education transformation, for example using educational data analytics to help pedagogical decision making.

DX in education is therefore defined here as *a shift in practices* for school principals, teachers, and students; *an active use of digital tools* in the classroom for teaching and learning and course development; and finally, *a shift even in social forms* through the affordances of digital tools. In education, DX has affected the internal work of organizations and forced the introduction of digital literacy teaching (Dörner & Rundel, 2021), and the development of digital skills and competences (Vuorikari et al., 2022). The COVID-19 pandemic has accelerated the footprint of digital technology in schools and has provided new teaching and learning experiences, as well as a need for change (European Commission, 2020). The pandemic also gave rise to a quick race against the clock to adjust to online pedagogies with all sorts of newly developed digital tools at all levels of education. Some education systems succeeded better than others and were able to set up strategies and continue to provide access to education in spite of the many challenges they faced (OECD, 2020).

Sweden, like many other countries around the world, has recognized the importance of DX in its education system. In 2017, the Swedish government implemented a national strategy aimed at enhancing the digital competences and skills of both students and teachers in schools (Regeringen, 2017). It entailed competence development for teachers and school leaders, collegial professional learning, appropriate technology, sufficient IT infrastructure and systematic quality improvement work to support equality between schools so that all children and students, as well as staff could develop “adequate” digital competence. As of July 1, 2018, changes were made to the national curriculum for compulsory and upper secondary school levels in response to the strategy, and subsequently also at the preschool level. Children and students were introduced to and now use digital tools in several subjects. For example, children use bots and tablets in preschool to learn basic programming, math and reading skills; digital learning materials covering all school subjects or just individual subjects are used by virtually all students in compulsory schools today. However, the lack of a clear plan on how to approach the transformation has been noted after the publication of the strategy. There have been efforts to provide guidance on areas to focus on for moving forward, such as the #Skoldigiplan report (Sveriges Kommuner och Regioner, 2020). This report however, acknowledged that there is still much work to be done to reach the desired levels of digital capacity. As a matter of fact, the level of DX in Swedish schools covers the whole spectrum: from the use of digital learning materials only, that is, no textbooks are used in all subjects, to individual teachers choosing not to use digital tools for teaching and learning and opting for traditional educational tools instead. Additionally, in December 2022, the Swedish National Agency for Education proposed to the Government a new national digitalization strategy, covering 2023-2027, which the Government sent out for consultation and audit. In May 2023, after the responses came back, the current Minister of Education decided to pause the digitalization strategy. The reason, according to the Minister, is that the strategy does not build on current evidence of brain and child development research in connection to the use of digital technology. Teaching and learning in the classroom should be developed by following clear scientific evidence from this research. Nonetheless, the number of digital tools for teaching and learning in Swedish schools is extensive, and it is not going to diminish by pausing the digitalization strategy. Sweden has reached a point where access is adequate at all levels of education, fitting Stage III of the DX journey.

The Status of Digital Learning

Contexts of digital learning

One of the most significant changes brought about by DX is the shift from traditional teaching methods to more personalized and student-centered learning. With the help of digital tools such as digital learning materials and online learning platforms, teachers can create customized lesson plans that cater to the individual needs and learning approaches of each student. Learning approaches refer to how students approach academic tasks, such as trying to obtain a holistic picture of what they learn, simply memorizing everything for the exams, or optimizing success in assessment through effective use of time (Masiello, 2005). The different learning approaches afforded by educational technology in the classroom highlight the need to rethink and restructure the learning environment with and around educational technology (Masiello, 2005), therefore, the context of Digital Learning (DL).

DL implementation in K-12 schools

The use of digital tools in Sweden has made learning more interactive and engaging at all levels of education and schools. Students at upper secondary schools use virtual reality (VR) and augmented reality (AR) technologies to explore complex concepts and ideas in a more interactive and immersive way, and with relative contribution to learning (Högström & Holm, 2020). They also use multimedia tools such as videos, animations, and simulations to enhance their understanding of various topics. Children in preschool and compulsory schools use bots and robots to learn programming and computational thinking (Hamidi et al., 2022; Zerega et al., 2022), or social robots to communicate and speak other languages[2]. DX has also made it easier for schools to collect and analyze data on student performance, both in compulsory and upper secondary education, but especially in higher education (Mohseni et al., Under review). Through online assessments and digital learning materials, teachers can use visualizations of data analysis on student progress, identify areas where students may be struggling, and tailor their teaching accordingly. These data can also be used by school administrators to monitor overall performance and identify areas where improvement is needed, in terms of individual students but also entire classes or schools. The field of data analytics in Sweden is growing mostly within the higher educational setting, with research groups in all Swedish universities (Nouri et al., 2019). Efforts in K-12 education are also relevant, due to the formal DX of the Swedish compulsory education system, although there is still limited research that demonstrates the clear benefits of using data analytics in K-12 educational practice in general (Aguerrebere et al., 2022; Mohseni et al., Under review). More specifically, larger research agencies in Sweden have not provided adequate funding for data analytics research in the compulsory education system (Nouri et al., 2019).

DL policies, projects/programs, strategies and R&D

Among DL projects/programs, one-to-one computing, where each student is provided with their own computer or tablet, is a popular approach implemented in many schools around the world, including Sweden. Already in 1996, the first one-to-one initiative started in a compulsory school in Färila (Naeslund, 2001). The results were mixed. On the one hand, the students gained digital skills, while on the other hand, the work became monotonous and basic knowledge decreased. The project was stopped. Other similar initia-

2 https://lnu.se/mot-linneuniversitetet/aktuellt/nyheter/2023/skolprojekt-med-roboten-misty/

tives started at larger scales in 2007 and 2010. In one of the larger one-to-one initiatives that took place in 24 municipal compulsory schools, the researchers determined that the computer provided a “more fun” learning environment but also a distraction, and a need for change in teaching (Grönlund, 2014). The same research determined that schools with good results and with highly educated parents could benefit from the introduction of one-to-one computing. While problems with student results became accentuated at schools with lower economic resources and for students whose guardians have only a secondary education (Grönlund, 2014), Swedish schools have nonetheless invested heavily in providing technology to schools, with the aim of improving learning outcomes for students. In 2018, the Swedish National Agency for Education reported that 49% of students in compulsory schools had access to one-to-one computing, up from 16% in 2012, while it was higher for older students in lower and upper secondary classes (Hall et al., 2021). However, the implementation of one-to-one computing also poses challenges for schools, such as ensuring that students use technology in a responsible and safe manner, managing technical issues, and addressing equity concerns related to access to technology. Nevertheless, the use of one-to-one computing in Swedish schools continues to be an important part of the country’s DX efforts.

The national strategy introduced by the Government in 2018 affected DL nationwide. The strategy included specific objectives on DL, setting the condition to develop “adequate” digital competence in all children and students through: a) an increased understanding of the impact of DX on society; b) to better be able to use and understand digital tools and media; c) an increased critical and responsible approach; and d) a strengthened ability to solve problems and put ideas into action with the support of digital tools and media. The Swedish National Agency for Education followed up the implementation of the strategy, and more specifically those objectives, with a report (Skolverket, 2022b). The report highlights that teachers, at all levels of education, feel they have sufficient digital knowledge, but they lack programming knowledge and a critical approach to information on the internet and social media. This means that the objectives are only partially fulfilled, while there is a need for competence development to better achieve the objectives, especially b-d. Those results are also corroborated by research. A study on computer programming in compulsory education grades 4-6 shows that teachers use ad-hoc strategies to facilitate learning, while lacking content knowledge in programming (Bjursten et al., 2022). Similar results were also found with teachers of older students in compulsory schools (Peggar & Shefram, 2020; Vinnervik, 2022). Consequently, there is a risk of inequalities among schools, and that programming will become disorganized or even omitted (Vinnervik, 2023). Research also corroborates the results of the Agency's report in terms of the approach to information and social media, that is, questions related to digital citizenship. In-service and pre-service teachers do not receive the necessary training to tackle the ethical, safe, and sound use of digital technologies or social media (Örtegren, 2022). Again, one consequence is that this can create unequal opportunities for students to develop active citizenship (Olofsson et al., 2020). Therefore, all this emphasizes the implementation gap between the good intentions of the Swedish Government and the reality in schools, calling for teacher preparedness.

The impact of COVID-19 on DL

The COVID-19 pandemic has brought to the fore both benefits and challenges to the DX in Swedish schools, as much as in the rest of the world. On March 19, 2020, a new law gave the government and school principals the ability to temporarily close the premises of educational institutions[3]. This meant that all educational activities were to be carried out online. Through regulatory changes, the government also made it possible for schools to be partially closed, so that only a small number of students could be offered teaching on-site. For example, students could be in school for practical moments, special support,

3 https://www.riksdagen.se/sv/dokument-och-lagar/dokument/svensk-forfattningssamling/forordning-2020115-om-utbildning-pa_sfs-2020-115/

and examinations. All forms of schools were affected by the change, except for preschools. Later in April, it became possible to apply certain provisions of the regulation on education in the school area and other educational activities in the event of the spread of certain infections, even if the school was open. On May 29, 2020, the Public Health Agency announced that upper secondary schools could reopen from June 15 (Folkhälsomyndigheten, 2020). This meant that upper secondary schools had to quickly adapt from remote teaching to on-site activities, while minimizing the risk of infection for students and staff. On June 9, 2020, the Public Health Agency changed its general recommendations regarding, among other things, personal responsibility in the workplace. For example, staff should have the opportunity to maintain distance, and individuals should avoid public transportation. To prevent students from traveling to school during rush hour on public transport, the government made feasible *hybrid education*, a combination of on-site and remote teaching. This announcement was made on July 16, 2020, and took effect on August 10. The possibility of remote teaching was then extended until June 2021. In short, circumstances changed rapidly, with all the possible consequences imaginable for school staff, students, and guardians.

Shortly after the first case of COVID-19 was confirmed, Swedish organizations, led by the Swedish National Agency for Education, swiftly organized to minimize the negative consequences of the pandemic in the school system. *Skola hemma was launched*[4]. It was a hub for all school staff to find educational material, digital tools, and information from authorities. Many developers of digital content, materials, or tools provided a link to their product free of charge to any school staff who wanted to use their product through the hub. A few days after the hub was launched, upper secondary education and all adult education was to be carried out remotely. The hub initiative made a profound difference and provided support to schools, teachers, and school boards, besides bringing together authorities and organizations which quickly focused

4 https://www.ri.se/en/our-stories/skola-hemma-supporting-learning-at-home

on rapid solutions in an unprecedented time.

Digital learning infrastructure

DL infrastructure in K-12 schools

It must be mentioned that Sweden already had a developed digital infrastructure, and the COVID-19 pandemic simply validated its existence. One-to-one computing is in place in over half of all compulsory and upper secondary schools, while it is possible to loan a computer in all other schools. Tablets are in use in preschools. High-speed internet or wi-fi connections are available in all schools and seem to work with good capacity. However, according to the Swedish Edtech Industry[5], the branch organization that gathers many educational technologies providers, Sweden has no central coordination of basic IT standards, leading to a lack of interoperability between systems, a lack of automated processes, and a lack of secure data analyses and transfer. Additionally, only during the last five years have several activities in terms of digital infrastructures matured[6]. For example, the Swedish EdTech Industry, together with other public and private partners, is currently working on IT standards for a smooth digital ecosystem, a forum for information standards within the school sector, data driven processes in schools, coordination of a national program for competence development of lifelong learning, and an educational technology map (Edtechkartan[7]) intended to help teachers and school principals with the procurement of educational technologies. Moreover, Linnaeus University offers a master's program in Educational Technology[8] (for now only in Swedish) that is meant to give professionals who work in the public or

5 https://swedishedtechindustry.se/standarder/

6 https://swedishedtechindustry.se/digital-infrastruktur-och-it-standarder/

7 https://edtechkartan.se/

8 https://lnu.se/program/utbildningsteknologi-masterprogram/vaxjo-distans-deltid-ht/

private sector the necessary skills to lead the DX in education sectors. Also, the Swedish EdTest[9], a testbed platform, was launched in January 2020 with the aim of improving the digital skills of teachers, developing better digital technologies, and bridging the gap between customers and suppliers by understanding the real needs of the users. Finally, the Swedish National Agency for Education contributes vastly to the digital infrastructure and finances professional development courses for teachers through the universities. The courses span from programming, computational thinking, and digital competences to digital storytelling, critical use of social media, and leading DX. Besides, the Agency offers a large number of online activities and courses and a large repository[10] of subject material readily available for all teachers.

Key statistics and practical examples

The fact that the digital infrastructure is good in Swedish schools can be partially attributed to the vision of the Government that holds that Sweden should be the best in the world in terms of making use of the possibilities of DX in school (Regeringen, 2017). Although, already in the 1980s, the presence of the personal computer had become increasingly common, and many teachers received further training to increase their digital skills. In the 1990s and 2000s, investment in the physical infrastructure, such as wireless network and computers in the classroom, took off (Swedish Edtech Industry, 2020). Processes such as digital attendance reporting, scheduling for teachers and more, were introduced in the 2000s. Statistics from 2021[11] indicate that the cost of K-12 schooling is about 320 billion SEK annually. These costs are covered by municipal taxes, which are approximately 43% of municipalities' total costs. Of these costs, circa 1%, that is, circa 3.7 billion SEK in 2018, is associated

9 https://edtest.se/en

10 https://larportalen.skolverket.se/

11 http://skr.se/skr/skolakulturfritid/forskolagrundochgymnasieskolakomvux/vagledningsvarpavanligafragor/samycketkostarskolan.2785.html

with educational technology investment by Swedish schools (Swedish Edtech Industry, 2020). However, much of the physical infrastructure was built in the 1990s, which suggests that large investments soon need to be made by municipalities to provide uninterrupted DL service in the classroom.

Features of DL

DX also presents some challenges for the Swedish school system. One of the main challenges is the digital divide, where students from low-income families may not have access to the same technology and resources as their peers. This can lead to unequal learning opportunities, and thereby widens the achievement gap. This notion was true before and during the pandemic, and still is. According to van Laar et al. (2017), seven core skills make up digital competence: technical, information management, communication, collaboration, creativity, critical thinking and problem solving. Having these skills means, on the one hand, having the technical skills necessary to use digital technology and services and, on the other hand, having the knowledge necessary to find, analyze and critically evaluate information in different media, that is, media and information literacy. This means that students will need a basic understanding of numeracy and problem solving, as well as literacy, since future careers contributing to a sustainable society will require increased levels of these proficiencies. However, during the last decade, the Swedish school system has been facing challenges in ensuring Quality Education[12] for all students and Reduced Inequalities[13] between students, two of the Sustainable Development Goals of the 2030 Agenda. More specifically, students of linguistic and ethnic minority groups demonstrate lower levels of achievement, both internationally (Denton & West, 2002) and nationally (Skolverket, 2019). An earlier PISA report shows that in Sweden, children born outside the country and refugees perform worse in mathematics than their counterparts in the oth-

12 https://www.globalgoals.org/goals/4-quality-education/

13 https://www.globalgoals.org/goals/10-reduced-inequalities/

er OECD countries (Skolverket, 2010). The reason behind this performance gap could be attributed to less support at home and in the school environment (Skolverket, 2010). A gender bias also exists, where boys outperform girls in mathematical skills, even though the gender gap is decreasing (Skolverket, 2019). Some of the aspects of mathematical knowledge are significant for the development of digital skills such as technical, critical thinking and problem-solving skills. PISA reports also show that students of linguistic and ethnic minority groups demonstrate lower levels of achievement, both internationally and nationally (Skolverket, 2010, 2019). Cultural traditions or socioeconomic conditions at home and in the school environment are once again factors playing a role in the variation of literacy quality (Lundberg, 2005). A gender bias in the opposite direction also exists; in this case girls outperform boys in literacy skills, even though the gender gap is decreasing (Skolverket, 2019). Technological advances are changing our society profoundly, and the heavy use of media allows for new affordances, that is, how we create and respond to information. Research on and development of literacy has been focusing on print and alphabetic literacy, whereas media tools have introduced the need to develop digital literacy (Selfe & Hawisher, 2004). Digital literacy is not solely print-based, but is multimodally varied, and additional aspects, for example, motivation to use online communication, availability and type of resources, convenience of access, availability of support, and possibility of quick feedback are changing the context of learning for learners and educators. As was true for mathematics, some of the aspects of literacy knowledge are also significant for the development of digital competences and literacies, such as information management, communication, collaboration, creativity, and critical thinking[14]. Again, the investment in longitudinal early intervention can help children develop and improve the foundations of the literacy knowledge trajectory in school, especially for students born outside of Sweden.

The COVID-19 pandemic reinforced the challenges in the K-12 school sys-

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tem in Sweden, especially in regard to equality and compensatory mission (Skolverket, 2022a). The measures taken to limit the spread of COVID-19 increased absenteeism among staff and children. The Swedish National Agency for Education assessed that increased staff absences in all forms of school also meant that the quality of teaching was negatively affected in many areas as the teaching could not be carried out as planned, which worsened conditions for the students' knowledge development. The agency suggested that, among other things, the impact seemed to have depended on how much remote teaching the students received, what it looked like in the activities before the switch to remote teaching, and the technical conditions and competence of students and teachers (Skolverket, 2022a). In terms of students, the report suggests that according to teachers and principals, those who, even before the pandemic, had humbler conditions to absorb the teaching, for example students with previously high absenteeism, students in need of support, or students with a mother tongue other than Swedish, did not reach the same levels of knowledge and skills compared to pre-pandemic results. Contrary to many other countries around the world, Sweden kept elementary and lower secondary schools open for the most part, and the fact that a school day could be maintained seems to have had a positive impact on well-being, as well as on knowledge development and social development.

Nevertheless, some difficulties persisted. In terms of teachers, the pandemic only accentuated the challenge for teachers to adapt to new technologies and teaching methods. Some teachers were already resistant to change, or lacked the necessary skills and training to use digital tools effectively, highlighting the need for professional development and training programs (Holmberg, 2023). The pandemic meant that many teachers and other staff had to adjust and manage both new technologies and new teaching methods in a short amount of time. Even though it was exhausting and challenging, new ways of working emerged during the pandemic, which, in some cases, will remain in education in the future, according to principals and teachers (Skolverket, 2022a). Above all, it is about an increased understanding of the possibilities of digitalization and new ways of using digital technology to develop teaching. Teachers state, for example, that they now use learning platforms to a greater extent to create clarity and structure in teaching and as a complement to the other face-to-face teaching in the classroom.

Kreitz-Sandberg et al. (2022) suggested that with regard to an international comparative perspective, the Swedish experience was strongly shaped by the following dimensions:

- A consensus among the government, authorities, and large parts of the political opposition that compulsory schools should have remained open.
- Upper secondary schools basically followed a strategy in the manner of those followed by universities – the hybrid alternative of remote and distance education.
- The relatively smooth transition to remote and distance education during the time of "emergency remote education" was only possible because both teachers and students were already accustomed to using digital tools in the teaching and learning process. Students had access to computers at home, schools had the necessary infrastructure, and teachers had knowledge of how to use computers.

DX has brought about significant changes in the Swedish school system. By leveraging technology, schools could be able to create personalized and engaging learning experiences that cater to the individual needs of each student. However, the digital divide, and the need for ongoing teacher training and professional development remain significant challenges that must be addressed, both in Sweden as elsewhere (European Education and Culture Executive Agency, Eurydice, 2019). Overall, the DX of the Swedish school represents an exciting opportunity to create a more innovative, student-centered, and effective education system.

Trends and Issues in Digital Learning

We conducted a literature search of the latest five years' publications (both in Swedish and English) by Swedish researchers to detect only the most recent and scientific trends and issues in DL.

Trends in DL

Among the trends we find the increasing use of digital technology, personalized learning, testbeds, programming, and generative AI.

Increasing use of digital technology. There has been an increasing trend of the use of digital technology and resources in teaching and learning in Sweden. This includes the use of online platforms, mobile devices, and educational software. According to Larsson and Teigland (2020), digital technologies are readily available and regularly utilized by teachers and students in Swedish schools. Municipalities often justify the adoption of new technologies by emphasizing the importance of aligning education with societal technological advancements. Additionally, they frequently highlight the potential benefits of leveraging these technologies to enhance students' performance. At the same time, the DX of Swedish schools has led to Learning Management Systems (LMS) becoming a prominent work tool within the classroom. This shift, referred to as "platformization," has introduced new practices that impact the daily work of both students and teachers, as LMSs become integrated into everyday school life (Grönlund et al., 2021). For instance, this may result in a loss of certain non-digital learning experiences, such as group work and physical interactions. Striking a balance between technology use and other forms of learning is essential to provide comprehensive education. Establishing a direct correlation between increased access to new technologies, increased utilization, and improved academic performance or grades is challenging. Therefore, while digital technologies can enhance the learning experience, it is important to ensure that they are used effectively and do not replace traditional methods of teaching and learning.

Focusing on personalized learning. Another trend in DL in Sweden is the focus on personalized learning. Digital tools can be used to create personalized learning experiences that cater to individual student needs and abilities. Research has shown that there has been a significant rise in the adoption of digital game-based learning as an educational tool to enhance pedagogy in Swedish schools (Brooks & Sjöberg, 2022), a form of personalized learning. However, ensuring that digital tools are used to create effective personalized learning experiences is a challenge that is going to be addressed in future research.

Assessing digital learning through testbeds. The global growth of the educational technology sector (also known under the name EdTech) has resulted in a diverse range of products and services, such as learning management systems and AI chatbots. The COVID-19 pandemic further accelerated this growth through increased investments in EdTech companies (HolonIQ, 2021). However, research has shown mixed results regarding the effectiveness of different types of educational technologies (Escueta et al., 2017). Only a small percentage of educational technology innovations have been externally evaluated, indicating that research captures only a fraction of the emerging EdTech sector (Vegas et al., 2019). Continued research is crucial to identify effective EdTech designs and implementation contexts. EdTech Testbeds, popular during the 2010s, assess EdTech effectiveness through co-creation, pilot studies, and randomized controlled studies (Vanbecelaere et al., 2023). Sweden is one of the world leaders in EdTech testbeds. The Swedish Edtest has been successful with over 200 educators and more than 50 EdTech companies participating in the testbed. The Swedish EdTest is brought to the fore as a good example of testbeds on a global scale (Vanbecelaere et al., 2023).

Learning to program. The Swedish national curriculum (Regeringen, 2017) promotes the development of digital skills within schools. Of those skills, programming and computational thinking are key. Programming by creating digital products was incorporated into the curriculum of Swedish primary and secondary schools in 2017 (Heintz et al., 2017), specifically within the subjects of Mathematics and Technology. The integration of programming and other emerging technologies has been found to present certain difficulties, emphasizing the importance of improved teacher assistance and support (Humble, 2023). According to a study conducted by Vinnervik (2022), which examined the preparedness of Swedish teachers in grades 1 to 9 for integrating programming into Mathematics and Technology courses, it was found that the teachers lacked confidence in their readiness for such implementation. In another study, Peggar and Shefram (2020) confirmed those results and showed that programming is applied only to a limited extent as stated in the curriculum, and teachers reason differently about the programming requirement. Thus, they implement it differently in the classroom. Programming courses for teachers are now offered at most universities in Sweden, and they span from simple block/visual programming to Python language programming. Those courses are very popular.

Making room for generative AI. Generative AI, and what is known as ChatGPT[15], is surely going to be the topic of the decade. Directly after the free introduction of ChatGPT to the internet in November of 2022, the infamous use of the chatbot turned ChatGPT into an instrument for cheating on schoolwork. This vilified use was so rapid that it caught many teachers and school leaders completely unprepared. In Sweden, ChatGPT was used for finding specific answers within the subject of History (Bulduk, 2023), and most probably many others, especially in tertiary education. However, this trend is so contemporary that there is still very little empirical research on this subject. Nonetheless, national magazines[16] and the internet are publishing articles on

15 https://openai.com/blog/chatgpt

16 https://www.dn.se/sverige/ratt-anvand-kan-ai-gora-svensk-skola-battre/

this trend almost daily, with many teachers worried about the fundamentals of their subjects being at risk. The National Agency of Education quickly tried to calm teachers down by providing guidelines on its use in the classroom, advising teachers against the adoption of using homework submissions at all[17]. Once the dust settles, generative AI will probably find its right place in the classroom, helping teachers assess assignments, improving language learning, helping students with special needs, and ultimately augmenting the relationship of human-generative AI.

The education systems of the Nordic countries (Sweden, Denmark, Finland, and Iceland, and Norway) had made significant progress in the last decade, even before the onset of the COVID-19 pandemic. In terms of digital readiness, all five countries are globally recognized for having highly favorable conditions for remote learning (European Commission, 2017; OECD, 2021). Overall, while DL has many benefits, there are also issues that must be addressed to ensure that digital technology is used effectively to support teaching and learning in Sweden.

Issues in DL

DL in K-12 schools in Sweden has also been shaped by the following issues: digital equity; lack of digital skills and training; data security; digital assessment methods; and digital citizenship.

Increasing digital equity for all. This is a major challenge in Sweden. Not all students have equal access to digital devices and internet connectivity at home, which creates a digital divide. For example, during the COVID-19 pandemic, students from disadvantaged backgrounds or rural areas faced difficulties in accessing online resources and participating fully in distance education (Lidegran et al., 2021; Skolverket, 2022a). Within early childhood education,

17 https://www.skolverket.se/undervisning/gymnasieskolan/betyg-i-gymnasieskolan/satta-betyg-i-gymnasieskolan

although creativity, play, and aesthetic work are already emphasized, the integration of technology and emerging materials into preschool education in Sweden remains incomplete. Consequently, a significant portion of the research on technology in early childhood education has concentrated on the utilization of iPads (Landwehr Sydow et al., 2021). Also, in the realm of early childhood education, there is relatively less emphasis placed on teachers and their professional development (Landwehr Sydow et al., 2021). However, efforts are being made by the Swedish National Agency for Education to address this issue by providing equal access to digital resources for all students in the future.

Lacking digital skills and training. Both students and teachers may struggle with limited digital skills and digital literacy skills, hindering their ability to effectively navigate and utilize DL platforms and tools. This can impact the quality of instruction and students' learning outcomes. There have been reports of technology education in lower secondary schools in Sweden deviating from the curriculum, and teachers experiencing widespread uncertainty about how to structure their teaching methods (Fahrman et al., 2020). A study encompassing 131 preschool classrooms in Sweden, Norway, and Finland revealed that even though 82% of the classrooms had multilingual children (many of which were new immigrants), the learning environment did not adequately acknowledge the students' multilingual abilities or the evolving societal trends in digital and multimodal literacy (Hofslundsengen et al., 2020). Moreover, teachers may not receive adequate training or professional development opportunities to effectively integrate technology into their teaching practices. Insufficient technical support and guidance can make it challenging for educators to leverage digital tools to enhance learning experiences, and Swedish researchers have confirmed that to fully leverage digital tools, a shift in teaching mindset is required, as simply providing digital tools alone is insufficient to achieve this objective (Grönlund et al., 2018; Leino Lindell, 2022). In the last few years, the demand for extensive digital technology professional development among teachers in schools across Sweden has risen (Forsling, 2019), and, especially after the COVID-19 pandemic, teacher training programs are being developed to address this issue. In the research project the authors have conducted (not yet published), we have been able to demonstrate that with increased digital competence, teachers more often judge substandard digital learning materials and take action. They testify to the uneven quality of the digital learning materials, which in the project can be communicated directly with the EdTech companies for further development. As the digital competence of teachers increases, so do the demands for qualitative digital teaching materials, and their voice is becoming a stronger influencing factor[18].

Ensuring educational data security. Ensuring online safety and protecting students' privacy is crucial in digital learning environments. The risk of cyber threats, data breaches, and inappropriate content poses challenges for schools, requiring robust security measures and strategies to safeguard students' well-being. As an example, the principal of a senior high school in the urban area of Kramfors, emphasizes the importance of addressing the sharing of student data between different stakeholders when it comes to providing personalized support and managing student information (Mattfolk & Emfeldt, 2020). According to him, the most significant challenge today is the ownership and management of student data by two private entities in Sweden. Consequently, the state must expend considerable funds to acquire access to essential data, including personal details such as names, addresses, and guardians. He describes this situation as a significant hindrance since the state does not have complete control over the information required for effective data utilization. As a result, the necessary infrastructure for developing relevant services for teachers, students, and parents is limited. Despite the need to digitize schools, the restricted access to data presents a barrier to innovation in the education sector (Larsson & Teigland, 2020).

18 https://www.smp.se/debatt/forskare-larares-okade-digitala-kompetenser-ger-ovantade-konsekvenser-e0c146c6/

Evaluating learning by digital assessment methods. Evaluating students' progress and understanding can be more complex in online learning. Traditional assessment methods may need to be adapted or replaced with new approaches to effectively assess learning outcomes and ensure fairness in grading. This in turn points to a need to develop new kinds of quality indicators for assessment and grading, for example, regarding digital multimodal text use (Sofkova Hashemi et al., 2020). Previous research conducted by Rönn (2022) demonstrated that within the Swedish school context, which places emphasis on evaluating and grading individual student accomplishments, students have transformed formal assignments into informal and social tasks. The students used various strategies, such as swapping computers, logging into peers' accounts and writing for them, and forwarding pictures with completed assignments. The author concluded that this behavior obscured the intended learning aspect, and hindered teachers' ability to conduct formative assessments effectively. A new aspect that is in every teacher's and student's mind now is the students' use of AI-supported chat robots, such as ChatGPT, to complete written assignments. This has become such an overall predicament that even the National Agency of Education now provides guidelines[19] on its use to teachers.

Teaching digital citizenship. As students spend more and more time online, there is a growing need to teach digital citizenship skills. These include areas such as online safety, digital responsibility, and ethical behavior online. Three Swedish authorities (Swedish Authority for Privacy Protection et al., 2020) have provided a set of guidelines to safeguard and support children and guardians in digital environments. For example, maintaining student engagement and motivation can be more challenging in digital learning environments compared to traditional classroom settings. Distractions, lack of face-to-face interaction, and limited social connections can affect students' participation

19 https://www.skolverket.se/skolutveckling/inspiration-och-stod-i-arbetet/stod-i-arbetet/rad-om-chat-gpt-och-liknande-verktyg

and enthusiasm for learning. On an opposite note, while digital games are a significant aspect of most Swedish youths' lives outside the classroom, their role within educational settings remains relatively unexplored and poorly understood (Mathe et al., 2019).

Addressing these issues requires ongoing efforts from policymakers, educators, and stakeholders to ensure equitable access to technology, provide comprehensive training and support for teachers, foster digital literacy skills among students, and implement appropriate security measures to protect online environments.

Conclusion

The present state of DL in K-12 schools in Sweden is relatively advanced compared to many other countries. The Swedish government has made significant investments in digital infrastructure and equipment for schools, such as computers, tablets, and smartphones. Many schools have adopted platforms to enhance teaching and learning, embracing the DX of education. The three levels of schooling—preschool, compulsory (elementary and lower secondary), and upper secondary—enjoy the use of several national online educational resources that support teaching and learning. These resources provide access to e-books, videos, interactive simulations, and learning materials on many subjects. The Swedish school system is publicly financed, and during the COVID-19 pandemic, the government was also able to provide funding and support for schools to invest in digital technologies and integrate them into teaching and learning through a national hub that offers complete free support and access to otherwise-paid resources.

Sweden has recognized the importance of DX and implemented a national strategy in 2017. The strategy aimed to enhance the digital competences of students and teachers, resulting in changes to the national curriculum. However, the implementation plan has been lacking, and there is still work to be done to achieve the desired level of digital capacity in Swedish schools. DL in Sweden is characterized by a range of features, including a shift towards personalized, student-centered learning. Through the use of digital tools such as online platforms and learning materials, teachers can create customized lesson plans that cater to each student's individual needs and learning approaches. These tools also make learning more interactive and engaging, with technologies like virtual reality and multimedia enhancing understanding and exploration of complex concepts. DX has also facilitated data collection and analysis, allowing teachers and administrators to track student progress and make informed instructional decisions. Sweden has made significant investments in one-to-one computing, providing students with their own devices, and programming. However, the implementation of digital technologies in schools has presented challenges, such as addressing the digital divide and ensuring responsible and safe technology use. The COVID-19 pandemic further highlighted the benefits and challenges of DX, with remote teaching becoming a necessity. The pandemic also emphasized the importance of supporting teachers in adapting to new technologies and teaching methods.

The authors have identified several trends and issues in DL in Sweden. These trends include an increasing use of digital technology, a focus on personalized learning, research and development actions in the form of EdTech testbeds, programming, and regenerative AI. Digital technology is being widely adopted in Swedish schools, with online platforms, mobile devices, and educational software becoming common tools. However, there is a need to strike a balance between technology use and other forms of learning to ensure comprehensive education. Personalized learning, particularly through digital game-based learning, is also gaining traction but requires further research to optimize its effectiveness. EdTech testbeds, like the Swedish EdTest, have emerged as an effective method for assessing and improving educational technology through collaboration between educators and EdTech companies. Programming and computational thinking are key components of developing digital skills in schools; however, teachers lack confidence in implementing them. The introduction of generative AI, specifically ChatGPT, has raised concerns due to its initial misuse for cheating on schoolwork; however, as more research and guidelines emerge, generative AI is expected to find a place in the classroom.

Alongside these trends, several issues are shaping DL in Swedish K-12 schools. Digital equity remains a challenge, as not all students have equal access to devices and internet connectivity at home, leading to a digital divide. The lack of digital skills and training among both students and teachers hampers the effective use of DL tools. Data security is a crucial concern, as cyber threats and data breaches pose risks to students' privacy. Furthermore, adapting assessment methods for online learning and teaching digital citizenship skills are additional challenges.

Despite all of this, digital technologies, and their affordances, are extensively used in Swedish schools at all levels, and efforts are being made to provide equal access to technology, offer comprehensive training for teachers, and promote digital literacy skills. The authors' own research project has shown that as the digital competence of teachers increases, so do the demands for qualitative digital teaching materials. Technology and teachers are two sides of the same "school mint." Ongoing collaboration among educators and EdTech companies is crucial to ensure the effective and equitable use of digital technology in Swedish schools.

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Trends and Issues of Digital Learning in Taiwan

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Abstract

Taiwan, renowned for its high digital competitiveness, is fully embracing the digital transformation where strategic decisions are made with the support of digital technologies in education. This chapter explores the emerging trends and issues resulting from this transformation, focusing on the country's initiatives and their impacts on various aspects of education. At the center of this transformation is the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan." Launched in response to the COVID-19 pandemic, it represents the most ambitious and comprehensive digital learning initiative in the history of the Ministry of Education (MOE). This plan was implemented amidst a global shift towards digital learning, incorporates lessons from the pandemic, and embodies the MOE's commitment to using digital technology to revolutionize Taiwan's education system and prepare learners for the future. This chapter offers a thorough review of the current state of digital learning in Taiwan, covering areas such as organization and budgeting, curriculum design and instruction, assessment and evaluation, professional development for teachers, course design, and beyond. It specifically underscores the emergence of digital learning platforms and teaching programs. The Taiwan Adaptive Learning Platform (TALP) serves as an example of how AI-driven platforms can foster adaptive learning, enhance student engagement, and cultivate crucial competencies such as self-regulated learning. Taiwan's dedication to the professional development of teachers is demonstrated through initiatives such as the "Empowerment Training of Digital Learning for Teachers" program. This comprehensive program equips educators with essential knowledge of digital tools, alongside strategies for their effective incorporation into classroom instruction. In conclusion, this chapter asserts that digital learning will increasingly dominate Taiwan's educational landscape, with a particular focus on the expanded application of generative AI. This outlook underscores Taiwan's readiness to lead the next wave of educational technology advancements.

Keywords: digital learning enhancement, educational big data, digital trend, digital transformation, TALP

Introduction

Structure of the schooling system in Taiwan

The education system in Taiwan is organized into four stages: early childhood education, compulsory education, upper secondary school education, and higher education (as shown in Figure 1). As for K-12 education, it commences with early childhood education and then transitions into an extended 6-3-3 system. This system includes 6 years of primary education and 3 years of lower secondary school, both of which are compulsory. At the upper secondary school level (including junior colleges), education is structured around a dual-track system. One track focuses on general education, while the other emphasizes vocational and technical education. Upon completion of K-12 education, students may choose to pursue higher education, typically a 4-year program. A brief description of each stage is provided as follows (Executive Yuan, 2023):

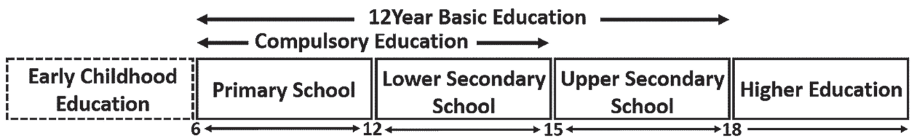
In early childhood education, according to the "Early Childhood Education and Care Act," children aged 2 years and above until they enter elementary school are considered pre-school children. Pre-school education is not compulsory and is not included in the school system.

Compulsory education in Taiwan includes two stages - primary and lower secondary school. Primary school spans 6 years, catering to students aged 6-12, while lower secondary school spans 3 years, serving students aged 12-15. Even though these two types of schools are independently set up, the "Grade 1-9 Curriculum Guideline," which was implemented in 2001, effectively integrates the curriculum and teaching across both stages.

Upper secondary school education is based on the "12-Year Basic Education" policy commencing from 2014. Upper secondary schools are classified into four categories: general senior high schools, vocational senior high schools, comprehensive senior high schools, and specialized senior high schools. Each category encompasses a 3-year curriculum, catering to students between the ages of 15 and 18.

In higher education, bachelor's degree programs at universities last for 4 years, Master's degree programs can range from 1 to 4 years, and Doctoral degree programs can range from 2 to 7 years. For those who are working or under special circumstances, each university has the discretion to extend the period of study.

Figure 1 Taiwan Education System



Note. MOE. (2022a). 12 year basic education related affairs. https://www.edu.tw

Digital transformation and current stage in Grades 1-12 schools

Taiwan, renowned as one of the top 21 countries in the IMD World Digital Competitiveness Ranking 2022, has all schools from Grades 1 to 12 firmly situated in Stage 3 - the Digital Transformation (DX) phase. Luo and Wee (2021) proposed that this phase is characterized by a wave of innovative and disruptive improvements in education, guided by strategic decisions supported by digital technologies. Schools are proficiently utilizing student-centric design thinking to extract valuable insights from students, consequently enhancing both internal and external customer engagement. A strong emphasis is placed on innovation within the overall educational approach, granting these schools a strategic competitive advantage and paving the way for sustained, high-level growth. This transformative journey primarily owes its momentum to the "Grades 1-12 School Action Learning Project" that ran from 2012 to 2018. This initiative seamlessly integrated information technology into teaching practices, paving the way for innovative teaching methods deeply grounded in student-centric design thinking, thereby marking the inception of Taiwan's journey towards digital transformation in education. Subsequently, from 2017 to 2020, the "Special Act for Forward-Looking Infrastructure 1.0" was put into action, aiming to enhance student engagement through the strategic use of technology in education. This Act guaranteed comprehensive internet connectivity in classrooms and provided students with digital devices such as tablets, facilitating digital learning.

In 2019, the“Technology-Assisted Self-Regulated Learning Project for Primary and Secondary School” was introduced, further consolidating Taiwan's commitment to digital transformation. Implemented across primary and secondary schools, this project set two key objectives: (1) Utilizing AI learning platforms to provide adaptive learning experiences that improve student outcomes, and (2) Leveraging technology to create a collaborative environment to enhance self-regulated learning. As part of this project, innovative teaching strategies, including the "Four Learning" approach and "Project-Based Learning," were developed. These strategies, which integrate advanced digital technology like AI, concentrate not just on the introduction of technology, but also its practical application in education. They are distinguished by three key features: (1) the use of technology to advance student-centric teaching methodologies; (2) the application of technology to lighten teachers' workload; and (3) the employment of technology to foster the development of lifelong learners among students.

Building on the successes of its previous policies, the COVID-19 pandemic in 2021 catalyzed Taiwan's digital transformation momentum. The government proposed the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan," which comprises three projects: (1) Enriching Digital Learning Materials, (2) Providing Mobile Devices and Internet Connection, and (3) Constructing and Analyzing Educational Big Data. Project 1 enhances the digital learning environment with a variety of resources, promoting student engagement and effective learning. Project 2 bridges the digital divide by ensuring all students have access to essential digital tools and stable internet connectivity. Project 3 employs big data analytics to refine educational practices and outcomes, promoting adaptive learning and educational equity. Collectively, these initiatives not only foster digital literacy but also enhance the quality of education, setting Taiwan on a path to a digitally empowered future.

The Current Status of Digital Learning

Contexts of digital learning (DL)

Digital learning policies and projects

The Ministry of Education (MOE) in Taiwan has introduced numerous digital learning policies since the turn of the millennium to harness the advantages of technology in enhancing learning in primary and secondary schools. These initiatives are classified into two primary categories: the implementation of Information and Communication Technology (ICT) infrastructure across campuses, and the enrichment of digital learning content for primary and secondary education. The policies within these categories are illustrated in two timelines, highlighting the progression of digital learning in Taiwan (as depicted in Figure 2).

In the implementation of ICT infrastructure in Taiwan, the first category of these policies focuses on the comprehensive application of ICT in educational settings. The key policies include:

- 1998-1999: Construction of Teaching Software and Hardware Environment in Primary and Secondary Schools, aiming to establish a computer classroom environment.
- 2009-2010: Actualization and Equalization of the Digital Education Project for Primary and Secondary Schools, striving to develop a digital

education environment.

- 2012-2016: Promotion of Application and Platform Service for the Education Cloud, intending to create a cloud learning environment.
- 2017-2020: Special Act for Forward-Looking Infrastructure 1.0, which led to the creation of smart learning classrooms.
- 2021-2025: Special Act for Forward-Looking Infrastructure 2.0, which aims to provide digital devices to nurture a smart learning environment.
- 2022-2025: the Promotion of Grades 1-12 School Digital Learning Enhancement Plan, aiming to provide mobile devices and internet connection.

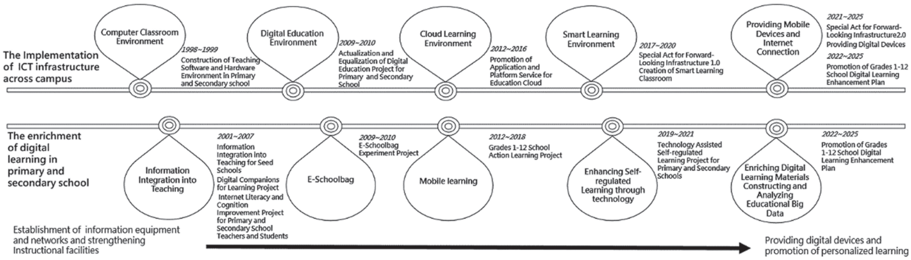
The ultimate goal of these policies is to establish robust information equipment and network infrastructure across campuses.

Moreover, the second category of the digital learning policies targets the enrichment of digital learning content for Grades 1-12 education. The key policies include:

- 2001-2007: the Project for Information Integration into Teaching for Seed Schools, the Digital Companions for Learning Program, and the Internet Literacy and Cognition Improvement Program for Primary and Secondary School Teachers and Students, all aimed at integrating information technology into teaching and learning.
- 2009-2010: The E-Schoolbag Project, designed to lighten students' school bags and reduce paper consumption.
- 2012-2018: The Mobile Learning Project for Primary and Secondary Schools, promoting ubiquitous learning.
- 2019-2021: The Technology-Assisted Self-Regulated Learning Project for Primary and Secondary Schools, aiming to foster self-regulated learning and nurture lifelong learners.
- 2022-2025: the Promotion of Grades 1-12 School Digital Learning Enhancement Plan, aiming to enrich digital learning materials and construct and analyze educational big data.

The overall objective of these policies is to enhance instructional facilities, thereby strengthening the teaching environment.

Figure 2 Timelines of Progression in Digital Learning



Note. MOE. (2022a). 12 year basic education related affairs. https://www.edu.tw

Digital learning implementation in Grades 1-12 schools

In light of the successful implementation of previous policies, the global trend towards digital learning, and further catalyzed by the COVID-19 pandemic, the Taiwan MOE rolled out the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan" in 2021. This plan, designed to span four years, encapsulates the following strategic initiatives: the "Enriching Digital Learning Materials" project, the "Providing Mobile Devices and Internet Connection" project, and the "Constructing and Analyzing Educational Big Data" project. The following is an overview of these projects (MOE, 2021):

- The Enriching Digital Learning Materials Project
  1. Digital instructional content mainly focuses on "subjects" and "core competencies": Digital content is mainly based on the content of each subject in primary and secondary schools, such as math, Mandarin, English, natural sciences, physics and chemistry, biology, earth sciences, and physics. Additionally, "core competencies" materials are being developed, such as math, Mandarin, and nature.
  2. Subsidies for schools to purchase teaching software and content: According to the teaching needs of teachers in each county and city,

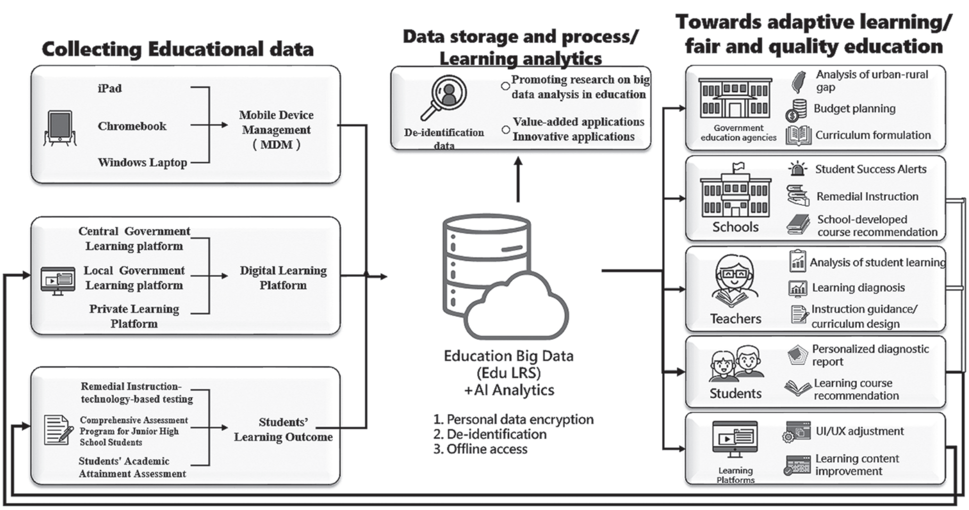
subsidies are provided for schools to purchase necessary digital instructional content and teaching software to enrich their digital teaching.

- The Providing Mobile Devices and Internet Connection Project
  1. Priority support for the mobile device needs of students in remote areas: Intending to assist the learning of students in remote areas, through "mobile device subsidies." We aim to achieve a 1:1 ratio of students to devices in remote area schools.
  2. Improvement of the external and wireless internet environment in primary and secondary school campuses: Targeting "campus external bandwidth" and "classroom wireless internet," we discuss improvement strategies to enhance the broadband connection of schools to the county and city education network centers.
- The Constructing and Analyzing Educational Big Data Project
  1. Collecting Educational Big Data: This project aims to establish a comprehensive educational database, focusing on collecting data related to learning engagement within digital learning environments and academic achievement metrics. The sources of these educational data include: firstly, the MOE's Mobile Device Management system (MDM), which tracks tablet usage data; secondly, digital learning platforms managed by public authorities (county and city governments), NGOs, and private companies; and lastly, databases from main testing organizations that compile students' academic performance data, such as standardized tests and entrance examinations.
  2. Data storage and process for learning analytics: The data collected above will be securely stored and processed in our educational database, adhering to the highest standards of security. These educational big data will be made available to educational authorities and institutions for learning analytics purposes. A portion of these educational data will be released as open data to the public. The open data will be used for value-added applications, fostering innovation in education,

and serving as training material for the development of big data and AI talent in universities.

3. The application of learning analytics: The ultimate goal of utilizing educational big data for learning analytics is to foster adaptive learning and ensure fair, quality education. In order to achieve this, the results derived from the analysis of educational big data will be provided to stakeholders such as government entities, educational institutions, schools, teachers, students, and operators of digital learning platforms. These results will inform various aspects of education, including evidence-based decision making, early learning alerts and assistance, curriculum development, instructional guidance and course design, personalized learning reports and course recommendations, as well as adjustments and optimization of digital learning platforms (as shown in Figure 3).

Figure 3 The Framework of the Constructing and Analyzing Educational Big Data Project



Note. MOE (2023a). Big Data Platform Construction for Education. https://pads.moe.edu.tw.

The impact of COVID-19 on digital learning

In comparison to other countries, Taiwan's students were not significantly impacted by the COVID-19 pandemic due to two factors: Taiwan's proactive COVID-19 prevention measures, and its forward-thinking implementation of digital learning infrastructure.

According to an OECD survey (UNESCO et al., 2021; Zeng & PCA Life Assurance, 2022), most countries were unable to keep the virus from crossing their borders, leading to an unprecedented global surge in cases. During the pandemic's peak in 2020, schools worldwide were entirely closed for an average of 79 days (excluding weekends and holidays), representing about 40% of the total instructional days in the academic year across all educational levels: pre-primary, primary, lower secondary, and upper secondary. However, the duration of complete closures varied significantly among countries with different income levels. High-income countries averaged 53 days, upper-middle-income countries 97 days, lower-middle-income countries 115 days, and low-income countries 88 days. In contrast, Taiwan's COVID-19 outbreak resulted in only 32 days of complete in-person class suspension, amounting to 16% of the year's total instructional days. These data demonstrate that Taiwan's education system was less disrupted by the pandemic compared to most countries worldwide.

In the pre-deployment phase, thanks to policies such as the Technology-Assisted Self-Regulated Learning Project for Primary and Secondary Schools and the Special Act for Forward-Looking Infrastructure 1.0, the Ministry of Education (MOE) undertook key preparations in digital learning (Kuo, 2020). These policies provided a strong foundation that helped mitigate the potential disruptions caused by the COVID-19 pandemic outbreak. Here are some anticipatory steps the MOE had taken before the COVID-19 outbreak:

1. Providing Guidelines for Online Teaching: The MOE issued guidelines concerning school closures and make-up classes ahead of the school

year, which enabled schools unaccustomed to distance learning to prepare effectively. The Ministry also established a central team to assist schools in preparing for online teaching and planning online lessons to guarantee learning quality. Experienced teachers were recruited to create promotional videos to guide other teachers in online teaching.

2. Offering Digital Learning Platforms, Digital Tools, and Resources: Even before the pandemic, the MOE was already proactively engaging with both the public and private sectors to secure access to digital learning content and platforms. These strategic negotiations proved invaluable when the pandemic hit, enabling the MOE to quickly establish a comprehensive platform that provided free access to a wealth of digital resources for students across Taiwan. This platform was crucial in facilitating the transition to remote learning during the pandemic. The required digital learning platforms, teaching materials, and tools were promptly supplied, thereby ensuring the continuity of the educational process. Renowned companies such as Microsoft Taiwan and Cisco Taiwan played significant roles in this transition by providing free online video conferencing systems. This comprehensive platform built by the MOE empowered teachers to plan lessons, assign students to relevant courses, and create learning content and tasks, thereby streamlining the transition to a virtual learning environment.
3. Supporting Learning Devices and Network Equipment: During the pandemic, the MOE assessed the state of digital learning and evaluated the need for online learning equipment and networks across different cities and schools. They prioritized the needs of remote and disadvantaged students, quickly procured tablets, laptops, and network sharers using emergency funds, and coordinated with major telecommunications operators to offer preferential internet access plans to disadvantaged families.
4. Promoting Distance Teaching Drills: Schools were urged to conduct online teaching drills to ensure teachers and students could effectively

handle online teaching and learning methods in the event of a pandemic outbreak. These drills served a dual purpose – they gathered valuable information about the process, and identified potential areas for improvement. Most schools participated in these drills, with each school encouraged to schedule at least one remote learning drill lesson for each class.

In the early summer of 2021, Taiwan faced an escalating COVID-19 crisis while awaiting widespread vaccine distribution. Consequently, the MOE had to suspend all in-person instruction. Swiftly, the "Learning never stops" strategy was enacted, initiating a transition to distance learning programs. Following the reinstatement of in-person instruction, educators began adopting hybrid teaching methods, a blend of online and in-person instruction, as a preemptive measure against potential future disturbances. Despite previous digital learning planning, the MOE identified multiple areas for improvement in the aftermath of the pandemic (Liu, 2023):

1. Enhancing Teachers' Readiness and Proficiency in Digital Instruction: Although Taiwan has made strides in digital transformation, surveys reveal that a significant fraction of teachers had no prior experience of remote instruction. This lack of familiarity adversely affected the quality of their online teaching. Nevertheless, the imperative for remote instruction during the pandemic has facilitated greater acceptance among educators. This presents an opportunity to stimulate more profound teacher engagement in digital learning, and encourages the MOE to strategize to enhance educators' skills in remote instruction.
2. Elevating Student Proficiency with Digital Learning Platforms: Surveys conducted during the pandemic indicated that a number of students faced challenges navigating digital learning platforms, primarily due to unfamiliarity. This struggle stemmed from an insufficient number of mobile devices in schools, which limited their opportunities to practice operating these platforms. Consequently, their lack of proficiency

resulted in reduced engagement during remote learning sessions, and hindered their ability to interact effectively with digital classes and complete assignments. It became clear that there was an urgent need to guide students towards proficiency in these platforms. Such a measure would ensure a smoother learning experience and active participation. Furthermore, improving device availability in schools would provide students with more opportunities to familiarize themselves with the operation of digital learning platforms, enhancing their digital learning proficiency.

3. Addressing Insufficiencies in Digital Learning Environments: Despite the MOE's prior planning for remote learning, the unexpected influx of online learners led to an unanticipated high network load. Several digital platforms faced interruptions due to excessive network traffic, implying that the current network infrastructure was inadequately equipped to handle the increased bandwidth demand. Additionally, despite prior initiatives to provide students with mobile devices, there was a shortage during the pandemic, inhibiting distance learning for all students. To tackle this, the MOE expanded academic network bandwidth, focusing especially on areas with limited connectivity, such as rural and remote regions. To further facilitate digital inclusivity, additional mobile learning devices were distributed, with students in under-resourced areas receiving priority.
4. Augmenting Digital Learning Materials: The shift to digital learning and online teaching during the pandemic necessitated a fresh array of digital course content and instructional resources. However, surveys revealed gaps in both the volume and quality of available digital learning materials. Firstly, the current content did not comprehensively address all subjects and grade levels. Secondly, the inconsistent quality of these materials often struggled to effectively engage students. Recognizing these challenges, the MOE reaffirmed its dedication to the development of high-quality, engaging learning resources. Additionally, the MOE

planned to partner with the private sector to procure vital resources and services for online instruction and learning. These concerted efforts are poised to stimulate the creation of adaptable online audio-visual teaching resources, customized to suit new course formats. These resources will not only equip teachers with the necessary instructional tools, but also support students in their journey of online self-learning.

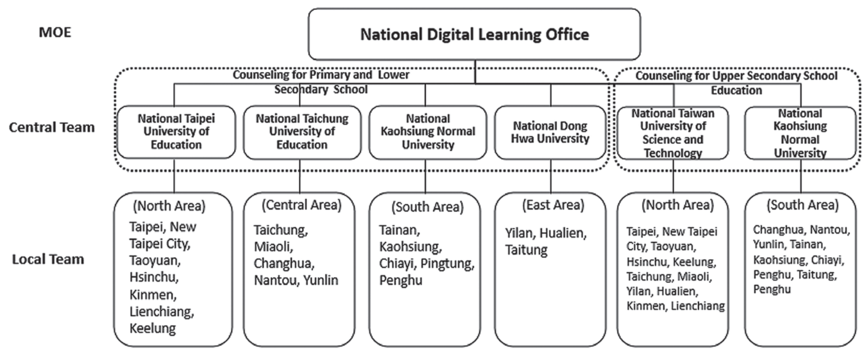
While the COVID-19 pandemic did not cause substantial disruption to students' learning in Taiwan, and there were no evidenced instances of learning loss during the outbreak, it undoubtedly expedited the shift towards digital learning. Based on the findings and the improvements mentioned above during the pandemic, in conjunction with global trends in digital learning and consensus among educational stakeholders, the MOE took the decisive step to implement the Promotion of Grades 1-12 School Digital Learning Enhancement Plan. This plan, launched in response to the COVID-19 pandemic, stands as the most comprehensive and ambitious digital learning initiative in the MOE's history. Not only does it incorporate the lessons drawn from the pandemic, but it also signals the MOE's commitment to harnessing the power of digital technology to transform Taiwan's educational landscape and cultivate learners who are prepared for the future.

Digital learning infrastructure

In the subsequent section, we will present an overview of Taiwan's current digital learning infrastructure, which is primarily based on the implementation of the "Technology-Assisted Self-Regulated Learning Project for Primary and Secondary School" and the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan."

Regarding organization, the MOE in Taiwan launched the Digital Learning Guidance Team in 2019 to efficiently implement digital learning. This team serves the dual function of coordinating digital learning operations across various cities and counties, and promoting the advancement of digital teaching methodologies among educators. Under the purview of the National Digital Learning Office, a specialized unit within the MOE responsible for digital learning affairs in Taiwan, the Digital Learning Guidance Team operates on two levels: The Central Teams, tasked with national governance, and the Local Teams, each responsible for their respective cities and counties (as illustrated in Figure 4). This structure is designed to foster effective propagation and continual improvement of digital learning practices.

Figure 4 The Organization for Digital Learning Guidance System



Note. MOE (2023b). Counseling and Support System. https://pads.moe.edu.tw.

Local Teams are tasked with regularly visiting schools to enhance technology-aided self-regulated learning, provide learning support to students, and facilitate remote teaching. Meanwhile, Central Teams primarily focus on several key areas. These include designing teaching methodologies related to digital learning, planning implementation strategies, evaluating the effectiveness of digital learning, and providing advanced digital learning training for teachers. Additionally, they assist local guidance teams with their operations. Central Teams also play a crucial role in supporting local governments in managing digital learning affairs. This involves sourcing specialized manpower, providing digital learning guidance personnel, and assembling teams for network setup and maintenance.

The Digital Learning Guidance Team is composed of carefully selected members, including digital learning experts, professors, specialist teachers, and administrative personnel. As illustrated in the hierarchical structure in Figure 3, there are six Central Teams, each of which is based in a unique university. To further the promotion of digital learning, the Digital Learning Office has established an office in every city and county, from which the Local Teams operate.

In terms of budget for its current push to advance digital learning, the MOE has committed a comprehensive budget of 20 billion New Taiwan Dollars for the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan," spanning from 2021 to 2025. The budget distribution includes 5.6 billion allocated for the "Enriching Digital Learning Materials" project, 14 billion for the "Providing Mobile Devices and Internet Connection" project, and 0.4 billion for the "Constructing and Analyzing Educational Big Data" project (Budget Center, 2022). A notable observation is that around 70% of the total budget is predominantly dedicated to upgrading mobile learning devices and augmenting internet speed. Meanwhile, projects involving the enhancement of digital content and analysis of educational big data serve complementary functions.

For the digital content and delivery, online learning platforms, such as the TALP - the official platform endorsed by the MOE, form the core environment for students' digital learning. As such, most digital learning content is tailor-made for compatibility with these platforms. When considering the approach to course design and delivery in digital learning, it can be analyzed from four primary perspectives within the context of TALP: instructional videos, interactive modules, simulations, and gamification.

1. Instructional video: It can be argued that instructional videos represent the most prevalent type of digital content. Their most distinctive characteristic is the facilitation of ubiquitous learning, enabling knowledge acquisition anytime, anywhere. Within the digital learning platform,

students can search for and repeatedly view instructional videos based on criteria such as course subject, grade level, learning content, and chapter names. Furthermore, some adaptive platforms like TALP, by incorporating personalized learning paths, offer a tailored approach to address individual learning weaknesses. These learning paths consist of targeted instructional videos coupled with assessments that are meticulously designed to improve specific areas of deficiency. Generally, instructional videos include embedded in-video quizzes or checkpoints to assess whether students have thoroughly grasped the learning material. As they progress through these videos, students can take notes on important content and pose questions about any learning difficulties they encounter.

2. Interactive modules: Interactive modules within learning platforms represent an emerging trend in the realm of digital resources, a development facilitated by significant advancements in technology. The primary advantage of interactive modules on digital learning platforms is their ability to leverage technology to foster a collaborative learning environment. These tools facilitate communication between students, teachers, or even computer-generated agents, thereby enhancing the learning experience. The TALP, for instance, provides features such as chatboxes or forums. These features enable students to engage in peer-to-peer communication and collaborative work, while teachers can use the same tools to guide and support students in their learning journey. Furthermore, TALP incorporates advanced tools such as an Intelligent Tutoring System (ITS) that simulates the assistance of a teacher or proficient peer. This unique approach allows students to scaffold their learning effectively, providing them with a richer and more immersive educational experience.
3. Simulations: Simulation-based learning materials serve a vital function in education, particularly in making abstract scientific and mathematical concepts more tangible. Enabled by recent advances in technology,

these tools can accurately recreate scientific phenomena, fostering a deeper understanding through experiential learning. In this regard, TALP incorporates “Physics Simulations” and “Math Laboratories” as key examples of these impactful simulation-based resources.

4. Gamification: To enhance motivation and engagement in learning, an increasing number of educational platforms are incorporating gamification as an integral part of their course design and delivery. Within the TALP platform, students are encouraged to complete educational missions or assignments in return for tokens or badges that can be utilized in gaming activities. One such game in TALP, "Guard Our Forest," does more than simply entertain. This game serves as an interactive learning tool, guiding students to familiarize themselves with various plant species native to Taiwan, combining fun with valuable knowledge acquisition.

As digital learning within Grade 1-12 education has progressed into the third stage of digital transformation, courses have been fully redesigned to center around the students. This evolution necessitates a diverse range of assessment methods to effectively evaluate students' performance. Moreover, learning platforms utilize these assessment results to produce actionable learning analytics. These insights are then visualized on the platform's dashboard, allowing both students and teachers to monitor learning progress. In addition, adaptive learning platforms generate individualized learning paths based on test results, ensuring that instruction is tailored to each student's unique needs and progress. To illustrate the diversity of assessments employed in educational platforms, we will use TALP as a key example in the ensuing discussion. It is crucial to highlight that the following three assessments reflect modern methodologies, distinguishing them from traditional assessment methods.

1. Cross-grade adaptive testing

Cross-grade adaptive testing differentiates TALP from other educational platforms, representing a significant evolution in personalized learning. TALP employs the Knowledge Structure Theory to construct a unique, customized cross-grade adaptive testing system. In this system, a two-tier knowledge structure is formulated for each subject, extending from Grades 1-12 (as depicted in Figure 5). The larger nodes in this structure symbolize competencies, while the smaller nodes represent specific skills or concepts. Arrows indicate the prerequisite relationships between knowledge nodes, each of which is color-coded: green for mastered areas, orange for those pending mastery, and gray-white for areas yet to be reached. Unlike conventional unit tests, TALP's AI-powered cross-grade adaptive testing is strategically engineered to diagnose students' learning deficiencies that span different grade levels. Furthermore, based on the results of the cross-grade adaptive test, TALP can generate a personalized learning path for each student (as illustrated in Figure 6). For educators, the diagnostic reports provided by TALP streamline the process of implementing differentiated instruction for their students, meaning that every student's learning journey can be tailored according to their individual strengths and areas needing improvement.

2. Conversation-based interactive assessment for complex competencies

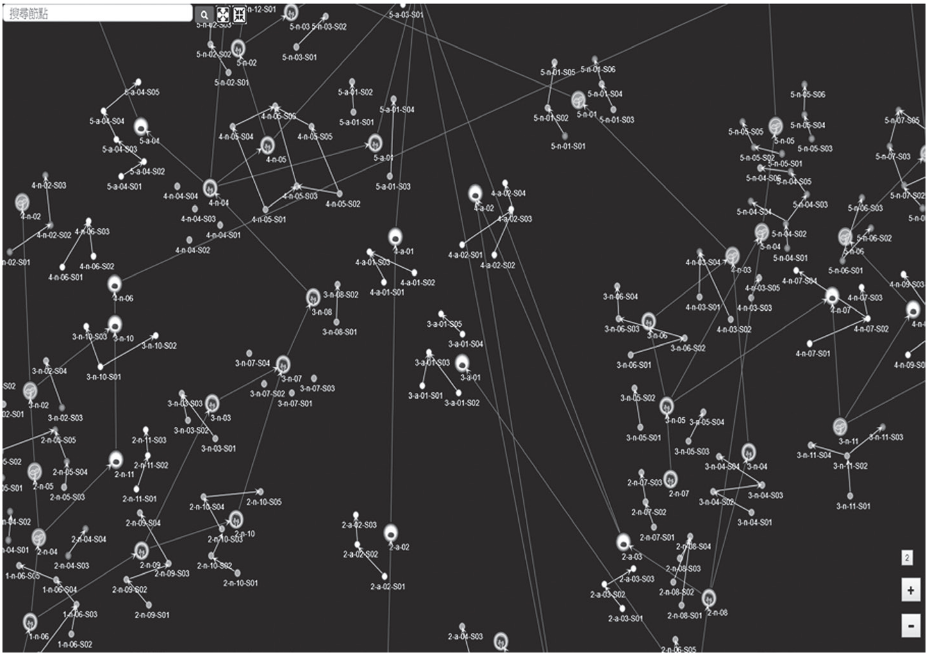
The paradigm in assessment within learning platforms is shifting to focus not only on academic achievement, but also on the development of competencies. To align with this trend, TALP has begun to incorporate conversation-based interactive assessments for evaluating complex competencies such as collaborative problem solving, global competency, creative thinking, and computational thinking (Graesser et al., 2017). This human-to-agent assessment approach has been shown to be as reliable and valid as the 2015 PISA CPS assessment (Kuo et al., 2020). Additionally, TALP's conversation-based assessment comes with an auto-grading feature, which can increase assessment efficiency by delivering immediate feedback.

3. Self-regulated learning questionnaire

Alongside academic achievement, many contemporary learning platforms now also emphasize cultivating students' self-regulated learning skills. This shift has made it essential to gauge whether students' self-regulated learning capabilities are being enhanced through the use of these platforms. To this end, TALP provides an assessment tool called the "Self-Regulated Learning Integrated Questionnaire." Unlike other self-regulated learning assessments, the unique design of this tool aims to encourage self-regulated learning skills while also gauging learners' self-regulated learning capabilities (Kuo et al., 2021).

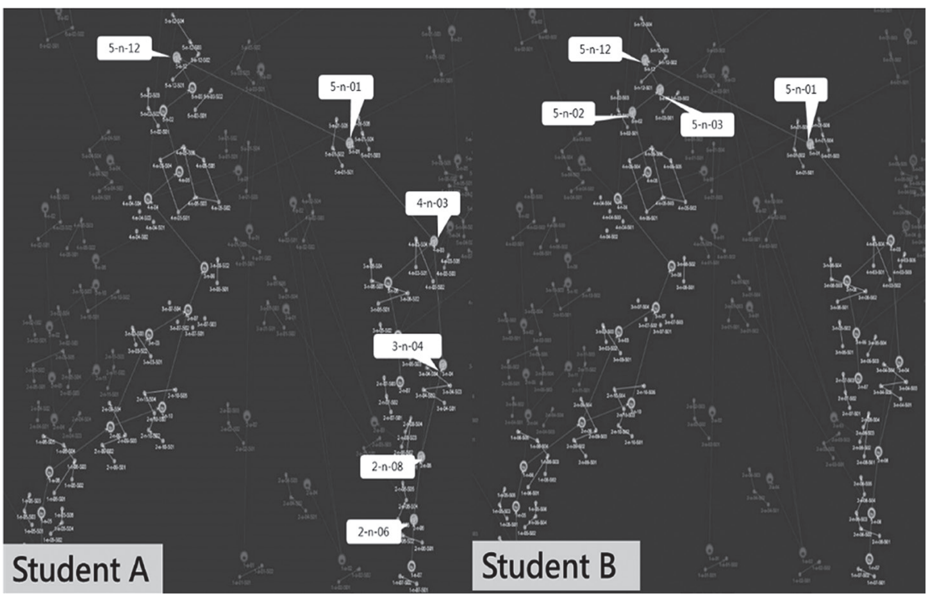
The questionnaire explores self-regulated learning across four dimensions: Cognition - by asking, "Do you know the following self-regulated learning methods?"; Behavior - by inquiring, "How often do you employ the following methods?"; Affect - by determining, "How significant is the learning method to you?"; and Technology-Assisted - by evaluating, "How helpful is the learning platform in your application of the following learning methods?" These self-regulated learning methods encompass goal setting, strategy selection, monitoring, and reflection.

Figure 5 Knowledge Structure in TALP



Note. TALP. (2023). A2 Digital Learning Workshop. https://adl.edu.tw/HomePage/home/.

Figure 6 Individual Learning Path in TALP



Note. TALP. (2023). A2 Digital Learning Workshop. https://adl.edu.tw/HomePage/home/.

For teacher professional development, while Taiwan's digital learning education has been flourishing, there had not been any officially published digital teaching guidelines for educators to use as a standard reference in their digital teaching development until 2022. In 2022, the National Digital Office of the MOE, referencing the digital guidelines published by the Office of Educational Technology in the United States, compiled the “National Digital Teaching Guide” for primary and secondary schools.

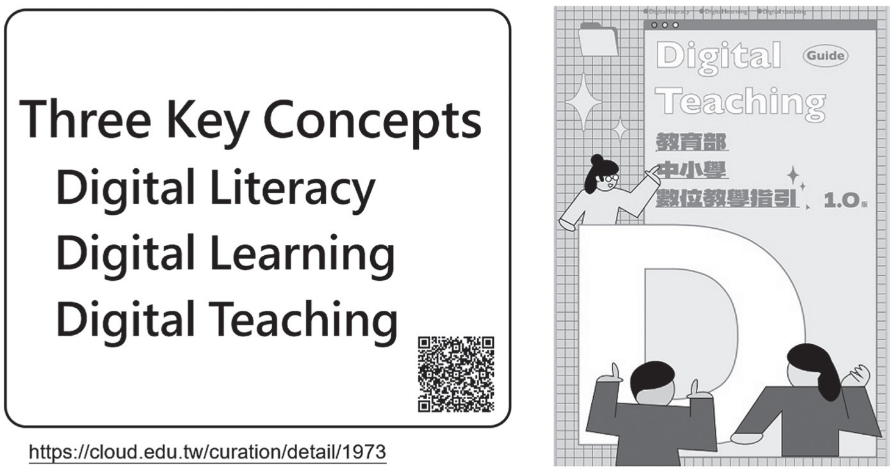
The National Digital Teaching Guide not only outlines digital learning trends, but also clearly defines key concepts such as "digital literacy," "digital learning," and "digital teaching" (shown in Figure 7). Furthermore, in response to the need for teacher empowerment, it provides a preparatory direction and various digital teaching examples for localities and schools when establishing digital teaching support systems. The National Digital Teaching Guide also aims to help teachers systematically use digital tools, choose suitable digital teaching materials for collaborative preparation and discussion, and facilitate long-term changes and influences in teaching styles (shown in Figure 8) (MOE, 2022b). With respect to the National Digital Teaching Guide, the principles of course design and teacher training sessions will be discussed as follows:

1. Course design

The Technological Pedagogical Content Knowledge (TPACK) framework of the National Digital Teaching Guide is illustrated in Figure 7. This framework suggests two primary considerations for teachers implementing digital instruction: "Digital Technology-Assisting Teaching" and "Digital Technology Integration into Subject Learning." "Digital Technology-Assisting Teaching" encompasses a variety of aspects such as joint lesson planning, instructional material consolidation, recording learning progress, facilitating discussion and communication, promoting search and collaboration, enabling creation and publishing, conducting testing and assessment, and analyzing learning data.

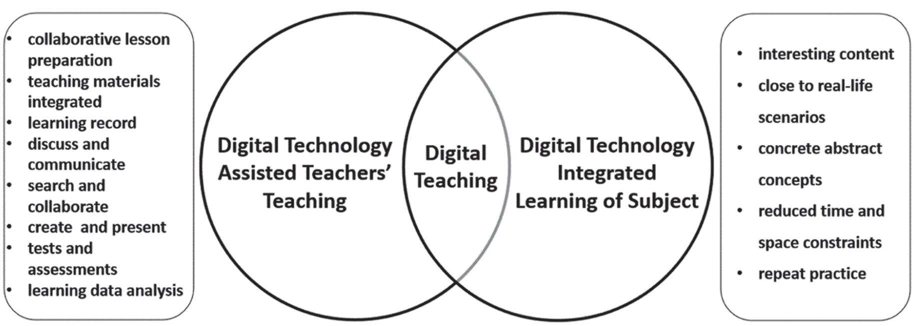
Conversely, "Digital Technology Integration into Subject Learning" emphasizes engaging content, relevance to real-life situations, tangible representations of abstract concepts, flexibility in time and space, and opportunities for repeated practice.

Figure 7 National Digital Teaching Guide



Note. MOE (2022b). Digital teaching. Ministry of Education.

Figure 8 The Framework of the National Digital Teaching Guide



Note. MOE (2022b). Digital teaching. Ministry of Education.

2. Training sessions

To enhance the digital teaching capabilities of elementary and secondary school teachers, the Taiwan MOE formulated the "Empowerment Training of Digital Learning for Teachers" (as shown in Figure 9) (MOE, 2023d; Ministry of Education Information and Technology Education Department, 2023). According to this framework, the training sessions offer two types of courses: basic and advanced.

Basic courses: The basic courses, mandatory for all Grade 1-12 teachers in Taiwan, aim to equip teachers with a foundational knowledge of learning devices, digital learning platforms, data diagnostic analysis reports, and the application of self-regulated learning teaching methods within these digital platforms. Additionally, digital literacy is integrated into these courses. There are three types of workshops provided in the compulsory training sessions, referred to as A1, A2, and A3. As of June 2023, 72% of Grade 1-12 teachers in Taiwan had completed A1 and A2 courses, with a goal of achieving full completion by 2024.

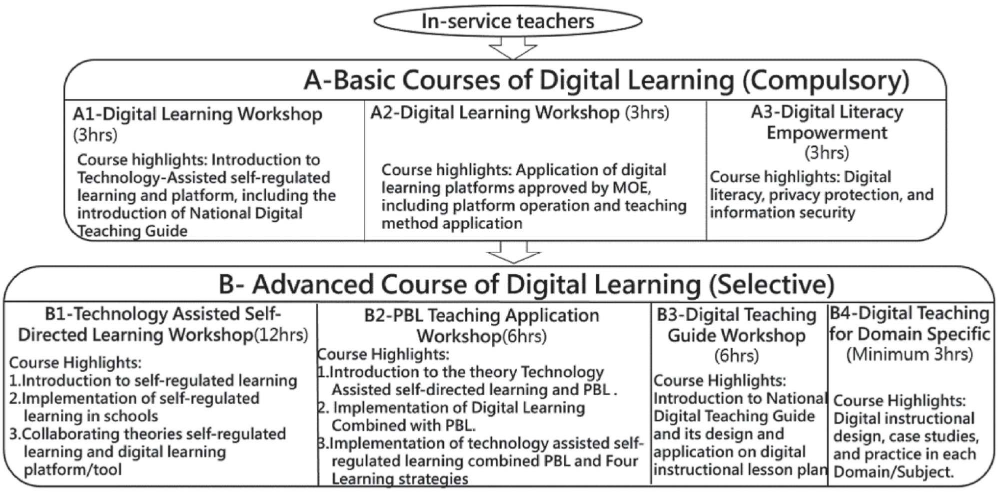
- A1 Digital Learning Workshop: This required 3-hour course introduces how to enhance self-regulated learning through technology, particularly digital learning platforms, provides an overview of the platforms commonly used and approved by the MOE, and the introduction of the National Digital Teaching Guide.
- A2 Digital Learning Workshop: Also a compulsory 3-hour course, this focuses on the application of digital learning platforms, covering topics such as understanding platform operations and the implementation of various teaching modes.
- A3 Digital Literacy Empowerment Training: This 3-hour course necessitates annual participation from at least 10% of teachers. It primarily focuses on areas like internet literacy, privacy protection, and information security, while excluding training on tool usage.

Advanced Courses: These elective courses were designed for teachers aiming to further develop their abilities to integrate technology and self-regulated learning theories into their teaching practices. There are four types of workshops available for teachers: the "Technology-Assisted Self-Regulated Learning Workshop," the "Project-Based Learning (PBL) Teaching Application Workshop," the "Digital Teaching Guide Empowerment Workshop," and the "Domain-Specific Digital Teaching Workshop."

- B1 The Technology-Assisted Self-Regulated Learning Workshop: This 12-hour course introduces the theories of self-regulated learning, practical applications of these theories in teaching, and strategies to enhance students' self-regulated learning using digital learning platforms or other mobile devices.
- B2 The Project-Based Learning (PBL) Teaching Application Workshop: This 6-hour course is oriented towards project-based learning. It not only delves into the implementation of PBL in teaching but also showcases how to integrate PBL with digital learning and self-regulated learning theories.
- B3 The Digital Teaching Guide Empowerment Workshop: This 6-hour course provides a comprehensive interpretation of the National Digital Teaching Guide. It aims to cultivate a shared understanding among teachers of the content of the guide, and instruct them on effectively utilizing it. The course highlights the application of design principles from the guide for planning digital teaching, utilizing co-preparation tools, and demonstrating various forms of digital teaching examples.
- B4 The Domain-Specific Digital Teaching Workshop: This 3-hour course, tailored to each teacher's specialty, explores digital teaching through the use of digital learning platforms and self-regulated learning theories. Unlike the other courses, this workshop focuses on specific domains such as Mandarin, Mathematics, English, and Science. The course shares case studies showcasing the contrast between general and

domain-specific teaching. It is recommended that teachers complete the B3 workshop before enrolling in this course to ensure a foundational understanding.

Figure 9 The Framework of Empowerment of Training of Digital Learning for Teachers



Note. MOE. (2023c). Empowerment Training and Lecturer List. https://pads.moe.edu.tw.

Regarding technology infrastructure, according to the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan," improving the network environment and providing mobile devices are two critical tasks for facilitating the technology infrastructure necessary for digital learning from Grades 1-12 in Taiwan. Its goal was to ensure internet access in each class and tablet use for students from Grades 1-12 by the start of the school year in September 2022.

- Network Environment Improvement: Under the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan," the scale of network enhancements is outlined in Table 1. The bandwidth improvement in schools is determined by the number of classes; schools with fewer than

12 classes will have their network speed increased to 300Mbps. Schools with 13 to 24 classes will be upgraded to 600Mbps, and schools with more than 25 classes will have their bandwidth boosted to 1Gbps. At the county and city government level, the six metropolitan cities will be upgraded to 80Gbps, while the remaining 13 counties and cities on the main island will see their networks upgraded to 40Gbps (MOE, 2021) (see Table 1).

Table 1 The Network Environment Improvement under the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan"

Level	Size	Network Bandwidth
School	< 12 classes	300Mbps
	13 -24 classes	600Mbps
	Over 25 classes	1Gbps
city	6 metropolitan areas	80Gbps
	Remaining 13 cities and counties	40Gbps

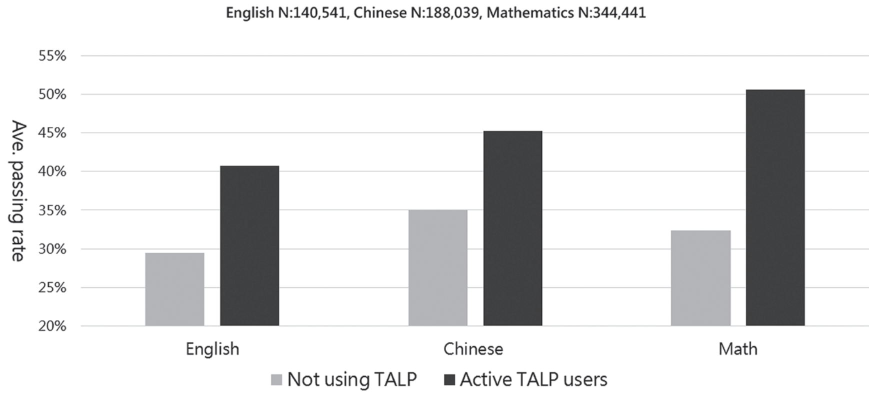
Note. MOE (2021). *Promotion of Grades 1-12 School Digital Learning Enhancement Plan (Approved version)*. https:/ /ws.moe.edu.tw.

- Equipping mobile devices and mobile device management: The MOE has fully subsidized the purchase of 610,000 learning devices and device charging carts for elementary and secondary schools. The number of tablets purchased has been planned according to the following allocation: each student in rural areas will have their own tablet, while in urban or metropolitan areas, a single tablet will be shared among six students. This distribution is designed to ensure that all students from Grades 1-12 have the opportunity to utilize tablets for learning in school. The devices were distributed to counties and cities nationwide in June 2022. Subsequent tasks included the installation of the Mobile Device Management (MDM) system and the distribution of relevant software. Regarding the types of devices, there are four major operating systems, including iPad, Windows, Chrome, and Android. The necessary operating system and devices are decided by the county and city governments, as well as high schools and vocational schools, through public meetings.

The purpose of purchasing the MDM is to establish a device management mechanism. Through the MDM system, it facilitates device management, distribution of teaching apps, collection of usage data, and prevention of students visiting inappropriate websites or potential internet addiction. It also provides appropriate assistance in case of device malfunction.

To ensure the success of digital learning, it is crucial that the effectiveness of all the aforementioned digital learning enhancement policies be assessed, particularly regarding their impact on students' learning outcomes. A large-scale study was conducted in 2022 with a significant sample size across different subjects: English (140,541), Chinese (188,039), and Mathematics (344,441). According to the PRIORI-tbt (Project for Implementation of Remedial Instruction-technology-based testing), a standardized test specifically designed to diagnose low-achieving students, the use of TALP for remedial instruction showed promising results. As shown in Figure 10, active TALP users showed passing rates of 40.71% in English, 45.26% in Chinese, and 50.59% in Mathematics. Conversely, the passing rates for students who did not use TALP for remedial instruction were lower: 29.41% in English, 34.99% in Chinese, and 32.34% in Mathematics. It implies that using TALP is likely to overcome the status as low achievers.

Figure 10 The Effectiveness of Using TALP for Low-Achieving Students



Note. Kuo, B.-C. (2023, July 29). *Promotion of Grades 1-12 School Digital Learning Enhancement Plan*. Parents Briefing for The Digital Learning Enhancement Plan for Grades 1-12 Students, Kaohsiung, Taiwan.

Features of digital learning

Based on the implementation of the aforementioned policies, the features of digital learning in Taiwan can be summarized as the following five aspects: reducing the digital divide, preventing student dropout, building a free and robust learning platform to ensure learning equity, enhancing learning and promoting self-regulated learning through collaboration, and leveraging educational big data and AI.

- In addressing the digital divide, the MOE in Taiwan gives priority to subsidizing mobile devices for schools in remote areas. The aim of this initiative is to achieve a 1:1 student-to-device ratio in these schools. In addition to this, the MOE is committed to improving network bandwidth in all remote area schools. This ensures that every student can use their tablet to access digital learning platforms or digital learning companions, providing them with comprehensive support for their learning.
- In the effort to prevent student dropout, the MOE in Taiwan has collaborated on integrating both the TALP and the Project for Implemen-

tation of Remedial Instruction-technology-based testing (PRIORI-tbt) systems. This cooperation aims to share data and foster adaptive learning; in other words, it helps in planning personalized learning paths for low-achieving students during remedial instruction. In terms of utilizing technology for low-achieving or at-risk students, the MOE has set a target where at least 50% of students use technology for their remedial instruction. Furthermore, the MOE ensures that all teachers conducting remedial instruction are adequately trained in the use of technology for this purpose. This approach allows low-achieving or at-risk students to enhance their learning outcomes with the help of blended learning assistance.

- In the realm of establishing a free and robust learning platform to ensure learning equity, Taiwan's MOE has built an AI-driven adaptive learning platform. This platform provides elementary and secondary students with a rich array of digital teaching content for a variety of subjects. This content includes instructional videos, interactive modules, simulations, and game-based learning categories. All of these resources are designed to promote academic achievement, self-regulated learning, learning engagement, collaborative learning, global competencies, and motivation. The platform also offers various types of diagnostic assessments to identify areas of weakness and provide adaptive learning opportunities. While most digital learning platforms impose usage charges, the TALP is free for all students and teachers from Grades 1-12 in Taiwan. This policy ensures that every student in Taiwan has equal opportunities to access educational resources provided by the government. Furthermore, the MOE has established a single digital learning portal system by integrating various digital learning platforms. This unified approach allows every student to use a universal account, called Open ID, to access multiple digital learning platforms. This system enhances accessibility and convenience, further promoting learning equity.
- In our quest to enhance learning and promote self-regulated learning

through collaboration, the "Four Learning" strategy plays a critical role. This unique approach combines the principles of flipped learning and the theories of self-regulated learning in the social model. This blended-learning strategy is divided into four components (Ho, 2014):

1. Self-Learning: This stage encourages students to take charge of their learning process, often initiating this before a lesson or task.
2. Co-Learning: This stage involves cooperative learning in groups, taking place after students have completed their self-learning. The primary goal is to promote peer monitoring of individual learning results and to foster peer scaffolding in problem solving.
3. Mutual Learning: In this stage, students learn from their peers across different groups. Learning is promoted through both collaboration and competition, facilitated by interaction and exchange of ideas between groups.
4. Teacher-Guided Learning: This final stage takes place after co-learning and/or mutual learning stages, and at the end of the lesson. Teachers, with the aid of technology, summarize the outcomes and interactions from the previous stages, guiding students to resolve their difficulties.

The "Four Learning" process significantly integrates digital technology with traditional teaching methods. Students are encouraged to preview their lessons using digital learning platforms, which can also present learning goals clearly. During the co-learning and mutual learning stages, tablets are employed as tools for peer monitoring and for providing or receiving feedback, all of which aid in the adjustment of learning strategies. In the final stage, teachers utilize the data collected from previous stages to guide students in reflecting upon their problem-solving skills. This innovative approach facilitates a holistic learning experience, amalgamating technology with traditional pedagogy to enhance student outcomes. The application of technology in co-learning and mutual learning stages underlines how the "Four Learning" strategy employs technology to boost collaborative learning.

- In the area of leveraging educational data and artificial intelligence, the MOE in Taiwan has focused on constructing an educational big data database and conducting learning analytics by aggregating and analyzing data from students' usage of learning devices and their learning journeys on various digital platforms. The evidence-based results have been providing stakeholders with a basis for decision making in policies and action for improving the quality of education. Additionally, the educational big data collected from digital learning platforms and mobile devices helps discern distinct learning behaviors or styles among students, providing crucial information for teachers to implement differentiated instruction.

Furthermore, artificial intelligence has been seamlessly integrated into digital learning platforms. Taking TALP as an example, it applies AI for adaptive testing to identify students' learning weaknesses. The results of this adaptive testing, in conjunction with AI and knowledge structuring, enables TALP to offer truly adaptive learning experiences. This progressive use of AI ensures that each student's unique learning needs are catered to, enhancing both the efficacy and the efficiency of the learning process.

Trends and Issues in Digital Learning

Trends in digital learning

According to the current development in DL, we summarize five directions which are the trends in DL.

The application of generative AI

Since the advent of OpenAI's ChatGPT, generative AI has garnered widespread attention from students, teachers, and researchers alike. Its potential applications in the realm of education are particularly notable. Generative AI algorithms like ChatGPT are designed to generate human-like text based on the input they receive. They can respond to prompts with answers that continue the discussion, offering interactive experiences that simulate conversations with a human. This makes generative AI a promising tool for personalized education. For one, it can be utilized as a personalized tutor, providing students with immediate feedback and assisting them in grasping new concepts. Because generative AI can process and respond to user input in real time, it can adapt to a student's unique learning pace and style, making education more personalized and engaging.

Moreover, generative AI can also be a powerful tool in facilitating language learning. Students learning a new language can use AI like ChatGPT to practice conversations, grammar, and vocabulary. The AI can correct errors, provide suggestions, and guide the students toward fluency. Generative AI can also be used to create dynamic learning resources. For example, it can generate practice questions, create unique story prompts for creative writing exercises, or simulate complex scenarios for problem-solving tasks. In addition, teachers can use generative AI to automate certain aspects of their work, such as grading assignments or providing feedback. This allows them to spend more time on high-value tasks like strategizing effective teaching methodologies and spending quality instructional time with their students.

Finally, researchers can use generative AI to analyze educational data, identify patterns, and derive insights that can inform teaching strategies and educational policies. Overall, the potential of generative AI in the field of education is immense. However, it is essential to understand and manage the ethical and privacy concerns that come with its usage, to ensure a safe and effective learning environment for all students.

Using AI tools for adaptive teaching

In striving to provide high-quality education, the effective utilization of artificial intelligence (AI) for adaptive instruction becomes pivotal. AI tools can be incredibly beneficial to educators in many ways, particularly in creating an adaptive teaching environment that caters to each student's unique needs and learning pace. AI allows for the personalization of educational content and the pacing of instruction based on students' individual abilities and performance. For instance, AI systems can analyze students' strengths and weaknesses by evaluating their performance in real time. This information can then be used to tailor subsequent learning materials and instructional strategies, thereby delivering a personalized learning experience. Moreover, AI can enhance adaptive learning through its predictive abilities. By identifying patterns in a student's performance and learning behavior, AI can predict potential challenges a student might face. It can also suggest suitable interventions, facilitating proactive adaptations to the learning process. This data-driven approach not only helps to enhance individual learning experiences, but also allows teachers to better manage diverse classrooms.

In addition, AI tools can also serve as valuable aids in teacher professional development. AI can provide insights into effective teaching methods and strategies based on analyzed data from various learning scenarios and student performances. Teachers can then leverage these insights to develop AI-integrated teaching patterns and methods that work best for their teaching style and their students.

In conclusion, AI presents an exciting avenue for bolstering adaptive teaching, thereby personalizing and improving the efficacy of education. While it remains uncertain whether AI will ever replace teachers, current experiences suggest that the successful integration of AI into teaching necessitates strategic planning, continual teacher training, and consistent evaluation of AI-enhanced teaching methodologies. AI should be viewed as a powerful tool that aids and amplifies teaching, rather than as a replacement for teachers.

Leveraging digital technology to strengthen core competencies

In an increasingly interconnected and fast-paced world, education systems are putting more emphasis on the development and enhancement of core competencies such as critical thinking, problem solving, collaboration, and global awareness. Digital technology plays a transformative role in this context. Digital learning platforms, AI-driven tutoring systems, and various interactive tools have the capacity to tailor learning experiences to individual student needs and preferences. For example, digital learning platforms like TALP can foster team-building skills and promote cooperative problem solving. They provide a virtual environment where students can work together, irrespective of geographical boundaries, mirroring the collaborative nature of the global workplace. Simultaneously, digital tools can help broaden students' perspectives and develop their global competence. For instance, virtual exchange programs or globally connected classrooms provide opportunities for intercultural interaction and learning, fostering empathy, respect, and understanding of diverse cultures.

Further, the use of educational big data for analytics allows for ongoing assessment and feedback, enabling students to understand their strengths and areas for improvement. Such insights can guide students towards purposeful learning, further strengthening their core competencies. In essence, the strategic incorporation of digital technology in education can significantly enhance the acquisition of core competencies, equipping students with the necessary skills to thrive in the 21st-century landscape.

Enrichment of game-based digital learning

The future of education will see a marked increase in the implementation of game-based digital learning. This learning approach has substantial potential due to its unique ability to engage and motivate students. By combining education and entertainment, it brings an element of fun into learning, sparking curiosity and increasing the desire to explore.

As for the modern game-based digital learning platforms, they enhance not only knowledge retention through interactive and immersive experiences, but also develop crucial 21st-century skills like problem solving, critical thinking, and collaboration. The ability to track progress and receive immediate feedback further adds to the appeal of these platforms. Moreover, the personalization features of these digital tools cater to various learning styles and paces, enabling a more inclusive and equitable education. Thus, the enrichment of game-based digital learning is an inevitable trend in the evolution of education.

BYOD and THSD for digital learning engagement

The evolving landscape of digital learning, particularly as it relates to mobile devices, has given rise to innovative trends such as Bring Your Own Device (BYOD) and Take-Home Student Device (THSD). The BYOD policy encourages students to bring their personal technological devices to school, promoting a sense of familiarity and ownership, which can enhance engagement and learning efficiency. While this allows for flexibility and personalization, it can inadvertently exacerbate the digital divide, as not all students have equal access to personal devices. In contrast, the THSD policy involves schools providing students with devices that they can take home, ensuring consistent access to learning materials and resources beyond school hours. This approach serves to counteract some of the equity issues inherent in BYOD by guaranteeing every student has access to the necessary technology, thus promoting a more equitable digital learning environment. It also ensures uninterrupted learning, particularly during disruptions such as the recent pandemic.

However, the successful deployment of both these trends demands comprehensive device management, robust security safeguards, and well-defined policies concerning device usage and maintenance. These trends not only shape the landscape of digital learning, but also respond dynamically to the evolving needs of students, emphasizing the crucial importance of digital literacy and safe online practices. These evolving trends play a critical role in equipping students with the skills and knowledge they need to navigate and succeed in an increasingly digital future.

Issues in digital learning

According to the current developments in DL, there are the following five issues that should be addressed to overcome challenges:

Enhancing the capability of primary and secondary school teachers and students to use AI-driven tools in teaching and learning

The advent of artificial intelligence (AI) has permeated various sectors, with education being no exception. As AI continues to infiltrate digital learning tools, such as educational platforms, there is an increasing need to strengthen the skills of both teachers and students in leveraging AI for educational purposes.

Teachers can participate in professional development courses that focus on AI applications in education. These courses may cover various AI tools, how they work, and best practices for using them in the classroom. This learning can be facilitated through workshops, online courses, webinars, or even peer-led training sessions. Besides, teachers can also learn from each other by sharing their experiences, challenges, and successes with AI tools. This collaborative learning could take place in learning communities, online forums, or at professional conferences.

For students, there are three channels available: (1) Instruction and Demonstration: Teachers or other experts can provide students with instruction on how to use AI tools. This instruction may include demonstrations of how the tools work and opportunities for students to practice using the tools themselves; (2) Project-Based Learning: Students can learn to use AI tools through hands-on, project-based learning experiences. These experiences provide an opportunity for students to learn by doing and to see how AI can be applied to real-world problems. (3) Guidance and Support: Teachers can provide ongoing guidance and support as students learn to use AI tools. This might include troubleshooting, providing feedback, and encouraging students to reflect on their learning process.

Enhancing digital literacy for education stakeholders

As digital technology continues to evolve at an unprecedented rate, it is critical that the digital literacy of all education stakeholders such as policy planners and formulators, school leaders, teachers, students, parents, NGOs, and businesses be addressed. We need to design and implement strategies that foster the progressive development of digital literacy, aligned with the unique needs of each stakeholder group. Such a strategy could involve ongoing training and education, coupled with the regular use of digital literacy indicators to monitor and assess progress. The focus is not only on improving practical technology skills, but also on cultivating a comprehensive understanding of how digital tools can be effectively and ethically used within an educational context. This ongoing development of digital literacy is a critical aspect of adapting to our increasingly digital world

Creating a sustainable digital learning environment

In order to safeguard the teaching rights of educators and the learning rights of students against man-made or natural disasters, it is of utmost importance to maintain data security during database and data collection processes, and manage crises effectively. By doing so, we enable the continuous refinement of educational policies and the application of data analytics to enhance both teaching and learning experiences. Establishing a sustainable digital learning environment also necessitates robust cybersecurity measures, ensuring that all users can engage in educational activities without fear of data breaches. By prioritizing security and sustainability, we can build a resilient foundation that is capable of adapting to unexpected challenges, thus providing a reliable, secure, and continuous learning journey for all stakeholders involved.

Ensuring data accuracy and others for data-driven decision making in educational policies

As digital learning continues to expand, an increasing wealth of student data is being generated and archived. These data, encompassing student learning outcomes, engagement levels, and other key performance indicators, hold significant potential for informing educational policies. They provide policy-makers with tangible evidence on which to base, review, and adjust educational strategies, potentially leading to more effective and targeted policies. However, data-driven decision making is not without its challenges. Ensuring data accuracy, comprehensiveness, and representativeness is critical, as the data need to capture the diverse realities of students across varying regions, socioeconomic statuses, and learning abilities. Data privacy and protection are other pressing concerns, particularly given the sensitivity of student information.

To overcome these challenges, policy makers should enhance their data collection, validation, and processing methods, while also implementing strong safeguards to protect privacy. The drive towards greater transparency in data-driven decision making invites wider scrutiny and encourages collective input. Despite the inherent challenges, the potential of data-driven policy making to create specific and successful educational strategies is remarkably substantial. The task involves not just confronting these issues, but also harnessing the power of data to effectively enhance educational policies.

Creating adaptive learning for inclusive education

One crucial issue in digital education involves creating and adapting learning materials for a diverse student body. While recent advancements in digital learning have emphasized adaptive learning, this focus primarily accounts for variations in academic abilities. Unfortunately, there is still a lack of sufficient consideration for inclusive education within the context of digital learning, especially concerning students with disabilities and those from indigenous backgrounds. To address this gap, efforts are needed to extend the concept of adaptive learning beyond academic abilities, incorporating aspects that cater to the unique needs of diverse learners. This includes developing universally accessible digital platforms, creating customized learning content, and integrating specific tools and features to improve accessibility.

Furthermore, establishing partnerships with organizations that specialize in accessibility and inclusivity is crucial to further develop adaptive learning for students with special needs. This collaboration aims to train educators to effectively use these enhanced digital tools in diverse classrooms. Also, feedback mechanisms that enable continuous refinement of learning materials to better fit individual student needs are being encouraged. These initiatives strive to ensure that digital education's transformative power benefits all students, fostering an inclusive learning environment that respects and caters to diverse learning needs.

Conclusion

Affected by the pandemic, digital learning and personalized learning in primary and secondary schools in Taiwan have taken a major leap forward. Through collaboration between the public sector and private entities, digital content has become richer and more diversified. At the same time, the introduction of artificial intelligence and educational big data into adaptive digital learning platforms has hugely promoted adaptive learning. There has also been a year-by-year increase in the coverage of teacher training for digital teaching enhancement and the positive use of AI tools in teaching. In the future, digital learning will continue to be expanded to off-campus and home environments, gradually extending the scope of digital learning.

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Trends and Issues of Digital Learning in the United Kingdom

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Abstract

This chapter reviews the current state of digital K-12 in the United Kingdom with emphasis on England. It gives evidence to substantiate the UK's high ranking in digital maturity studies and analyses. The chapter begins by summarising England's K-12 system and the factors of the National Curriculum and National Exams which produce a uniform system despite the wide variety in size, purpose, organisation and funding of schools. It describes the digital policy interventions, funding schemes, large-scale projects and influential reports in the period 2010-23, demonstrating that decisions taken more than ten years ago have continuing effects today, and that the pandemic rapidly accelerated existing trends rather than setting a brand new direction. A broad view is taken of infrastructure covering technology, leadership, budgets, course design/delivery, ensuring student success, staff development, quality/inspection, and analytics. It provides data, with key examples, supporting the main trends analysed - bandwidth, school networks, software, end-user devices, and content. It covers topics often omitted in such reports, such as private schools, homeschooling, virtual schools, open content, online national examinations and the overlap of K-12 with the post-secondary sector. It reviews key issues: structural disorganisation leading to fragmented procurement of a plethora of systems, the multi-dimensional isolation of K-12 including the disconnect between school and post-secondary digital approaches and systems, lack of clarity on the role of parents, the rigidity of the school day/week/year limiting the scope for blended digital learning, and the promise but problems of advanced technologies.

Keywords: digital schools, virtual schools, online schools, primary school, secondary school

Introduction

The structure of the K-12 system in the UK

The UK does not have one single UK-wide model for its school system. Despite being part of the UK, Scotland retains its own education system with four years to study for a bachelor degree - the three other home nations have 3-year bachelor degrees but one more year in schools. The description that follows is based on England (over 85% of the UK population). The UK government's *Department for Education* has jurisdiction only over education in England.

K-12 provision comprises state schools and private schools. Private schools receive no state subsidy - they educate around 7% of students, rising to around 18% for students at Sixth Form (Green, 2022). There are two main types of state school: municipality-based schools, but now also semi-autonomous directly-funded schools with "more freedom to change how they run things" (Department for Education, n.d.) – with Academies and Free Schools as subtypes. Municipalities are called "local authorities" in England - over 150 of them (Wikipedia, 2023a).

No UK teacher uses the term "*K-12*" - instead the term *school sector* is used. There are 13 grades - *years* - at school. Years 12 and 13 are *Sixth Form* - in these students study A levels or level 3 vocational qualifications. Students at school are called *pupils*. The *age of majority* when children become adults is 18, but from 16 children gain some rights, and are then called *young people*. Typically schools are divided into *primary schools* (children age 5-11) and *secondary schools* (age 12-16 or 12-18). A few municipalities still have *middle schools*, ages 9-13 (see Figure 1 and Table 1).

Private schools are called *independent schools* in government documents, but "public schools" in general conversation - which is very confusing outside the UK (Good Schools Guide, 2023). The word *college* usually means a state-funded post-secondary non-higher education institution, a *further education college* (FE college). Confusingly, several colleges teach school-age pupils, mostly in Sixth Form Colleges or departments. Even more confusingly, some Sixth Form Colleges are changing to Academies, a type of state school (Department for Education, 2023c).

The National Curriculum is a complex set of guidance documents (Department for Education, 2014) on what to teach at each stage of the compulsory school system (Enser, 2020). There has been little serious attempt in England (until Covid) to "put the curriculum online".

National Examinations specify how all this is assessed, both at the end of the compulsory school system and at the end of the Sixth Form. The *General Certificate of Secondary Education* (GCSE) is the exam that most students take at 15-16. Students are encouraged to take at least five GCSE subjects including those in the *EBacc* (English Baccalaureate) (Department for Education, 2019b). Students can leave school at 16, but if so they must enter another educational institution or get an apprenticeship or trainee post (The Education Hub, 2023). Normally two years after GCSEs, students wishing to enter higher education or higher-level employment sit A levels, available in over 80 subjects. Typically students take three or four (McLennan, 2022). Many A level subjects can be studied fully online, though rarely by students in state-funded schools.

There is a parallel strand of vocational qualifications that many students study - including BTEC (UCAS, 2023). In 2020 the government introduced T levels, "broadly equivalent in size to 3 A Levels" (Department for Education, 2023h). In 2023 the government announced that work will start on a new *Advanced British Standard* to subsume A levels and T levels into a broader qualification, more consistent with Scotland and many other countries (Prime Minister's

Office, 2023) - however, the proposals will take years to implement and have already generated much criticism even from supporters of the government (Spectator, 2023).

Figure 1 Structure of the School System in the United Kingdom/England

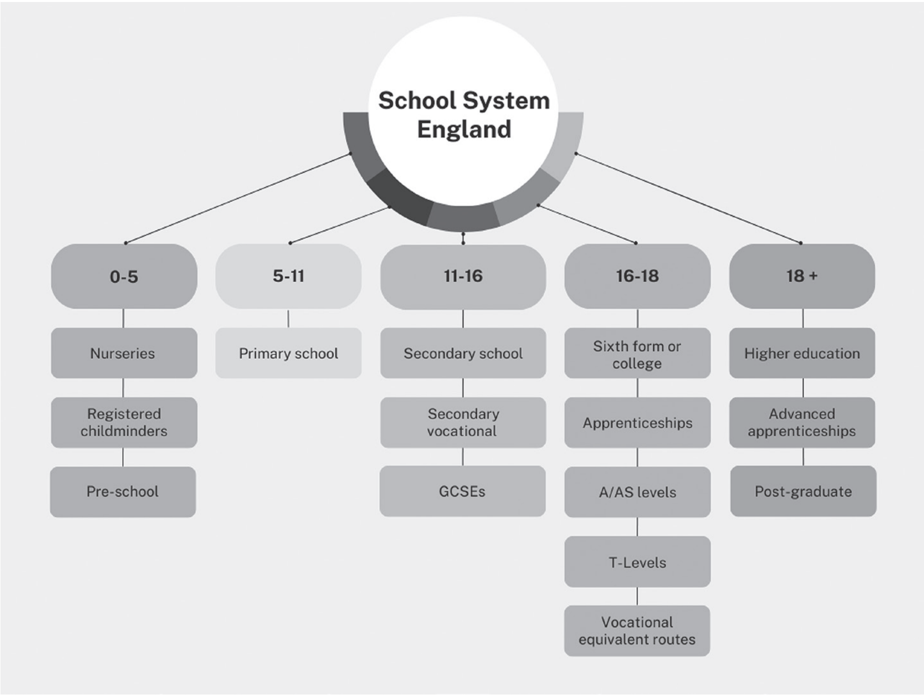

Table 1 Schools in England - Summary Data

Number of schools	24,442
Pupils in schools	9,073,832
Teachers in schools	468,371
Average class size	26.7

Note. Education Statistics, 2023b.

Overview of digital transformation in schools

Most UK schools are at the end of Stage II substage Digitalization - noting that this stage never finishes as systems are updated. The UK scored 86.45 overall in the IMD *World Competitiveness Digital Ranking 2022 Report*, with its ranking rising from 10 in 2018 to 16 in 2022 (IMD, 2022).

The Department for Education commissioned a report on digital maturity in 2022, based on UK surveys and methodologies, concluding that "around 9% of the schools surveyed were high in maturity, 31% were low and 60% moderate" (CooperGibson Research, 2022).

There have been many digital policy interventions in education in England, from the 1990s through to around 2011. The government agency Becta was key to these but was closed in 2011 as part of recession-induced cuts (Gov.uk, 2011). This led to many years of minimally visible *policy*, but continued investment and development in practice.

Digital K-12 provision remains incomplete in terms of digitization beyond Stage II substage Digitalization: however there are many examples of good practice.

The Status of Digital Learning

Contexts of digital learning: policies, strategies, programs, projects, research

This policy area is called "ICT for education" in UK papers. There is a long history of policy development (TPEA, 2023) from 1967 with the formation of the UK *Council for Education Technology* - later the *National Council for*

Education Technology and finally Becta. A history of "30 years of technology in education" (Rossi, 2015) notes that Becta was a "landmark", set up in 1998 with a *UK-wide remit for all education*, not just K-12 in England. The ambitious scope of Becta is clear from two reports for the Becta project *CAPITAL*: (Bacsich & Pepler, 2008) on ICT-induced change in *all* education sectors, and (Bacsich, Harrop, & Lackovic, 2010) on international issues.

Policies and strategies

There were just *two* main policy announcements *before* those of the Covid era 2020-22 - *Harnessing Technology* in 2005 and *Realising the Potential* nearly 15 years later (2019), punctuated by the unexpected closure of Becta in 2010 (see Table 2).

The 2019 policy was planned to set the tone and funding envelope for subsequent years of activity. However, higher-level political challenges meant that there was little government, public or teacher attention paid to education technology matters until the Covid lockdown started. Nevertheless, this policy facilitated the funding schemes for Covid responses. The main commitments were: full-fibre internet connectivity to schools, cloud services, demonstrator schools and online training courses for teachers/leaders (Department for Education, 2019d).

Table 2 Summary of Policies and Strategies

Date	Policy	Reference	Description
2005	Harnessing Technology: Transforming Learning	(Department for Education, 2005)	"the … first cross-sector e-learning strategy. … what the technology can do for ... transforming the experience of learning."
2010	Government closes Becta	(Department for Education, 2012)	"schools are now in a position to manage much of this themselves."
2019	Realising the potential of technology in education	(Department for Education, 2019d)	"... to do more to explore and reap the benefits that technology can bring. …the first step…"

National programmes

In addition to the policies there were three main programmes - *National Grid for Learning* (1998), *Laptops for Teachers* (2002-05) and *Building Schools for the Future* (2003-10). The last was not a specific ICT programme but had a substantial ICT strand within it (see Table 3).

Table 3 Relevant ICT-Related Programmes

Date	Policy	Reference	Description
1998	National Grid for Learning	(Selwood et al., 2001)	"a gateway ... a curated collection of links to resources and materials of high quality ... to support schools ...." (Wikipedia, 2023b)
2002-05	Laptops for Teachers	(Royal Borough of Kensington and Chelsea, 2004)	"announced ... January 2002. An extension of the initiative from two to four years and an increase in funding was announced ... January 2003."
2003-10	Building Schools for the Future	National Audit Office	"to renew all 3,500 English secondary schools over the 15-year period 2005-2020, ... to entirely rebuild half the school estate, structurally remodel 35 per cent, and refurbish the rest. Refurbishment includes *providing new ICT to recently built schools*." (National Audit Office, 2009, p. 7)

Commissioned reports

Despite the lack of actual policy announcements there was a constant stream of funded reports on various aspects of digital K-12 - the six most important are tabulated in Table 4.

Table 4 Research Reports

Date	Policy	Reference	Description
2010	Shaping contexts to realise the potential of technologies to support learning	(Manches et al., 2010)	"The final report on the CAPITAL project (Curriculum and Pedagogy in Technology Assisted Learning."
2012	The Impact of Digital Technology on Learning	(Higgins et al., 2012)	"Recommended strategies towards the improvement of effective use of technology in the classroom."
2015	Education Technology Action Group: Our reflections	(ETAG, 2015)	Explored how educational technology could be harnessed to transform teaching and learning experiences, including barriers and opportunities.
2022	Education technology for remote teaching	(Department for Education, 2022d)	A review of UK evidence on remote teaching, including case studies highlighting what worked well.
2022	Future opportunities for education technology in England	(Vicentini et al., 2022)	"Aimed to provide insights to the future of the EdTech market in England, considering likely developments in digital technology and education policy."
2023	Innovating Pedagogy 2023	(Open University and UCT, 2023)	This annual report highlights emerging trends and technologies in education.

Digital learning implementation

All levels and types of schools have some level of digital education. A key report showed that "64% of schools in the UK are … embedding technology" (EdTech Assessment Tool, 2022). Secondary schools use free tools like G-Suite for Education or Microsoft Teams to communicate with learners, set tasks and provide resources. Most primary schools have digital use too - for example, Shireland Technology Primary School has classrooms equipped with "interactive smart boards, to laptops and iPads, to audio-visual recording technology, to programming and robotics kits" (Shireland Technology Primary, 2023).

In 2018 a key report claimed that shortage of STEM skills was costing £1.5billion (Ledgerton, 2018) - work to alleviate this was enabled by the *UK Science and Technology Framework* with 10 key actions to achieve "becoming the most innovative economy in the world" by 2030 (Government of the UK, 2023). *STEM Learning* champions education in this area, providing resources, training and partnerships to primary, secondary and post-16 teachers and learners (STEM Learning, 2023).

The *National Centre for Computing Education* (NCCE) states that "54% of students studying AS and A level have engaged with Isaac Computer Science" (NCCE, 2022). Isaac is a free online platform. *Barefoot Computing* was set up in 2014 with resources to prepare primary school teachers for the changing computing curriculum, "reaching 3 million pupils and over 85,000 teachers in the majority of primary schools across the UK" (Barefoot Computing, 2023). The *Code Club* has 8,500 Code Clubs in schools (Code Club, 2023).

COVID-19 digital learning acceleration

The pandemic provided an urgent need for schools to accelerate their digital transformation, implementing systems or work-arounds to provide their students with learning available online. In primary schools, school websites were often utilized to create a dedicated area where year groups could access and download relevant work or links to signposted topic videos. Secondary schools generally, in time, provided course work and homework with feedback via Zoom, Google Classroom or Microsoft Teams - few had done that before.

Early in the pandemic there was very little *action* from government for a rapid move to remote digital K-12, with a few key exceptions, such as authorising funds for purchase of devices. However, in a way typical of the UK, a combination of government agencies, the BBC, large IT vendors, charities, schools, teachers and parents rapidly achieved useful results - with context a series of policy recommendations from the Department for Education 2021-2022.

Within two weeks of the first lockdown the BBC announced a major extension of its pre-existing educational offerings both via TV and online to start at the beginning of the summer term in England and the three other home nations. The service focused on *BBC Bitesize Daily* (BBC, 2020).

Vendors such as Microsoft, Google, Zoom and others ramped up their cloud-based offerings and provided free services to schools. Deployment of Google Classroom or Microsoft Teams was supported by the *Get Help with Technology* programme (Department for Education, 2020).

The leading commercial vendors of VLEs - Instructure, D2L and Anthology - all provided substantial free support and advice to their education clients during Covid. This was of great value to UK *universities and colleges*, but in the UK few schools use such systems. One school running Brightspace produced a case study on its experience during Covid which for them was far less problematic than for most schools (Deans, 2023). Moodle reopened their *Moodle Basics for Teachers* course in March 2020 and their forums were an active supportive environment (Moodle, 2020).

The Oak National Academy was the main content action that the government took. It was created in April 2020 with funding from the Department of Education. It has now "developed 40,000+ resources with the support of 550 teachers and delivered over 150 million lessons in [the] online Classroom" (Oak National Academy, 2023a).

In contrast, in Scotland, there *had already been* a well-developed service SCHOLAR offering online content and courses covering the Scottish secondary school curriculum up to all the usual exit points (SCHOLAR, 2023). During the pandemic Scotland developed this further, into the *National E-Learning Offer* (2022).

Funding

The government ensured that substantial funds were released to provide devices and networks to support remote learning, via the *Get Help with Technology and High Speed Internet* initiatives (see Table 5).

Tabe 5 Funding Schemes to Support Remote Learning

Date	Funding scheme	Reference	Brief description
2020-22	Get Help with Technology: £374m	(Department for Education, 2020)	This provided devices and mobile data, with "over £160 million to support remote education. ... 220,000 laptops and tablets for disadvantaged children" (FE News, 2020).
2022	High Speed Internet: £150m	(Department for Education, 2022a)	To help schools in Education Investment Areas upgrade their networks.

Digital learning challenges during the pandemic

There were six key challenges faced by teachers as below:

1. The **rapid shift to online learning** presented an urgent requirement to find ways to transition to remote learning when most teachers had no skills in the area. The plethora of systems used in schools made effective rapid mass training impossible - educators were using over 50 different platforms (Gibbons, 2020).

2. **Digital divide** surveys demonstrated the lack of access thousands of pupils had to a suitable device or the Internet: "7% did not have fixed broadband and

4% had access only via a mobile phone" (Ofcom, 2021, p. 4).

3. **The challenges of adapting delivery for different needs**. Teachers had to cope also with face-to-face teaching and delivery of learning packs to some students.

4. **Digital literacy: students, teachers and parents**. Digital literacy acceleration was promoted through use of online tools. Vendors, associations and schools provided webinars and guidance in how to use tools and systems where appropriate.

5. **Online security and safeguarding** presented challenges in relation to reliance on digital platforms and the online safety aspects (Department for Education, 2021).

6. **Mental health and well-being** were key issues for young people who were suddenly without their usual daily term-time routine and support structure. A mental health and wellbeing survey was updated throughout the pandemic - the final report noted that "symptoms of depression and post-traumatic stress disorder (PTSD) … significantly increased in children and young people" (Office for Health Improvement and Disparities, 2022).

Digital learning infrastructure

Technology infrastructure

In general terms, each school in England has a good technology infrastructure:

1. Most schools have a high-bandwidth connection to the internet.
2. All schools have a local area network with wired and wireless provision.
3. Most schools have a selection of devices to access the network - desktop and laptop devices with keyboards but also tablets with touch screens - although the user:device ratio is rarely even close to 1:1 for student devices.

4. Almost all schools use electronic whiteboards for audio-visual equipment (data projectors are much less common).
5. End-user software has a focus on content development and editing - for textual documents Microsoft Word on many devices, and Google Docs for Chromebook or tablets.
6. Servers (for file storage, etc) are gradually moving to the Cloud.
7. Schools have a collection of tools to handle resource-based learning, collaboration, and assessment. They also have tools to supply online content. However, schools normally deliver such functions via separate tools and apps - only a few run a university/college-standard VLE.

Schools in Scotland, Wales and Northern Ireland benefit from a more centralised approach to provision and centralised services. These models are relevant exemplars for English regions:

- Scotland had *Glow* - a "digital environment to support learning across the whole curriculum" to schools "*including independent schools* and teacher education colleges/universities" (Glow, 2023). Many schools have internet connections and services supplied by the *Scottish Wide Area Network* (SWAN, 2023).
- Wales had *Hwb* - "to support teaching and learning activities" but only for "maintained schools" (Hwb, 2023).
- Northern Ireland had *C2K* - which "provides a core ICT service to all grant-aided schools … hardware, software, connectivity and technical support" (Department for Education NI, 2023).

In contrast, in England, provision of funding and support for this is decentralised, with different types of solution in different parts of England and for different types of school.

England is unlike many countries of similar population size in that it has no standard subdivision into regions with stable boundaries. There used to be a structure of nine government office regions in England - from 1994 these had some devolved functions and were the constituencies for elections to the European Parliament and reports to the EU. In the 2000-2009 decade they were used for the ten Regional Broadband Consortia in England and for procurement purposes - a few of these survived into the National Education Network (NEN, 2023), but most were dissolved in the mid-2010s (Rotherham Borough Council, 2014).

In 2010 the devolved powers were abolished and regions' political relevance ceased when the UK left the EU in 2020. Instead there is a complex and ever-changing set of groupings - counties, districts, unitary authorities, city mayors - aiming to support schools and provide school services. In addition, many schools are Academies, autonomous from their municipality. This makes it hard for education ministers to get policy implemented - in the inimitable words attributed to a former Prime Minister, "you pull the lever, and nothing happens" (Stewart, 2014).

The creation of *Academies* (Gove, 2010) and grouping them into Multi-Academy Trusts (Department for Education, 2016) introduced an alternative non-geographic devolved structure. The Department for Education did set up a regional structure to try to cope with this which did not align with Government Office Regions. However, in a wise move, the government announced in 2022 that they would be "aligned to the 9 regions used elsewhere in government" (Department for Education, 2022b).

The data that follows is mainly taken from the *EdTech Survey 2020-21* (CooperGibsonResearch, 2021).

1. School connection to the internet

Many schools do not yet have access to high-speed internet (a 1 Gbps connection or more). "Primary schools (49%) ... were significantly more likely to experience lower bandwidth … compared to secondary schools (21%)" (CooperGibsonResearch, 2021, p. 16). This was no doubt one reason why the government announced a plan in 2022 for all schools "to have high speed internet by 2025" (Department for Education, 2022a). The announcement contained specifications to guide schools in provision, with clauses on full fibre, a backup link and IT security (Department for Education, 2022f). These specifications are part of a set (Department of Education, 2023k) which also cover colleges.

2. On-premises networking (wired and wireless)

All schools have a local area network with wired and wireless provision. However, in 2018 "Only 78% of primary schools and 81% of secondary schools believe they are well resourced with Wi-Fi" (BESA, 2018). In 2019 the *Realising the potential* policy document admitted that "schools, colleges and universities can struggle with the interruption to teaching and the wasted time … that accompany poorly implemented local networking and Wi-Fi." (Department for Education, 2019d, p. 13).

However, in 2021 the EdTech survey reassuringly claimed some progress: "Wireless and broadband connectivity in school [are] 'small' barriers rather than 'big' barriers" (CooperGibsonResearch, 2021, p. 97). By 2022 government policy was clear: *use the Wi-Fi 6 standard*, with detailed recommendations (Department of Education, 2023k).

3. End-user hardware (students and staff)

CooperGibsonResearch (2021, pp. 17-18) provides detailed data on hardware:

> *Primary schools were more likely to use tablet devices (teachers and pupils), whereas secondary schools were more likely to use laptops and desktop computers.*

> *... 1:1 access to mobile devices for pupils was extremely low. Just 1% of primary schools and 2% of secondary schools provided access to at least one mobile device (tablet or laptop) for every pupil.*
>
> *Amongst primary schools, 15% had access to one mobile device for every two pupils and 21% for every three pupils. Three-fifths of primary schools (61%) had access to one mobile device for every four pupils or less (ratio of 1:4 or lower).*
>
> *Pupil access to mobile devices amongst secondary schools was much lower. Just 3% had access to one mobile device for every two pupils and 9% for every three pupils. Eighty-four percent of secondary schools had access to one mobile device for every four pupils or less (ratio of 1:4 or lower).*
>
> *Device ratios for desktop computers were higher amongst secondary schools, with two-fifths having a device ratio of 1:5 or more (compared to 2% for primary schools)*

The Department for Education seems cautious about its approach to supply of what it calls "appropriate devices" (laptops, tablets, etc) to students. There is no scheme to ensure that every child has an appropriate device, indeed there is no statement that an appropriate device is even required, On the other hand it accepts that these devices are useful for learning and assumes that students will somehow gain access. There are schemes to ensure that many "disadvantaged" children have such devices supplied, but with complicated rules.

By the end of the pandemic, 1.96 million appropriate devices were delivered and over 100,000 routers (Department for Education, 2022e).

4. Audio-visual equipment

"The vast majority of schools had interactive whiteboards or blackboards: primary 97%, secondary 91%" (CooperGibsonResearch, 2021, p. 17).

5. End-user software (students and staff)

End-user software is usually Microsoft Office and/or Google Docs.

6. On-premises servers and off-premises servers including Cloud

Servers (for file storage, etc) are often still located in-school but are gradually moving to centralised services and the Cloud (CooperGibsonResearch, 2021, p. 16).

7. Central applications

Schools have tools to supply online content to students - from publishers like Pearson (2023b) and TES (2023) or new-generation providers such as Khan Academy (2023). A popular UK-specific tool is GCSEPod, claimed to be "for learning or revising for your GCSE/IGCSE exams" (GCSEPod, 2023).

One key bit of information is that 70-80% of UK schools used the management information system SIMS (Kunert, 2021). This shows that some uniformity is feasible.

Leadership and budgets

Leadership development for head teachers and senior teachers is well developed, with *National Professional Qualifications* (NPQs) delivered via courses, normally free to study, supplied by "approved providers" (universities, charities, churches, etc.) (Department for Education, 2023i).

In terms of funding and budgets, the funding formula for a state-funded school in England is set by government (Department for Education, 2022g). The formula is complicated - in summary (Department for Education, 2023j), "average per-pupil funding in schools for 2023-24 is £7,460". This does not all go to schools: *spending by schools themselves* (excluding spending at Sixth Form Colleges) was £5,974 per pupil in 2022-23 (Institute for Fiscal Studies, 2023).

State spending per pupil is around 2/3 of the undergraduate tuition fee (cap) of £9,250 in higher education (Office for Students, 2023). Since university staff are paid more on average than teachers and many do research as well as teaching, it may seem surprising that schools cannot afford the integration and sophistication of ICT solutions, in particular VLEs, that universities have. It is even more surprising given that some higher education providers charge fees closer to £6,000 than £9,250, and yet still afford such tools. Admittedly, universities have ways of earning more than £9,250, from non-UK students and post-graduate programmes, as well as entrepreneurial activity.

One budgetary nuance for schools is the pupil premium, "to improve educational outcomes for disadvantaged pupils", currently £2.9 billion (Department for Education, 2023d). This can be up to £2,500 per pupil, but more usually £1,000.

Course design and delivery

The need for a design approach is understood by teachers, and there are many guidance documents (Ferrell et al., 2018). There are several methodologies which learning designers can use (University of Bath, 2023) - the most widely used is *ABC*, from University College London (ABC Learning Design, 2023). However, there is no evidence that ABC and similar approaches are used in schools. Teachers are more familiar with "lesson design", usually called "lesson planning", but see less need to regard a group of lessons as a coherent learning design. There could be several reasons for this, including that course syllabi are more under teacher control in post-secondary education, due to the lack of a national curriculum.

Delivery of lessons via the whiteboard, "present in over 90% of classrooms in Britain" (Twinkl, 2023) is a dominant pedagogic approach.

Another obvious pedagogic approach is homework. There is no statutory overall requirement for students to have to study at home. Instead, such matters are left to each school - the government keeps no records of how much homework is done. However other agencies carry out surveys - one stated that on average UK children do 4.9 hours per week, with more in sixth form and much less in primary school (The School Run, 2023). In theory this homework time could be used for home pre-reading, allowing "flipped classroom" activities during the school day; in reality, homework usually involves some task whose output is graded or discussed in class the next day.

Student success for digital learning

Student success for digital learning depends on many factors. The critical ones are already in the list of topics in this section. The main schools-focused EU schemes covering such aspects, DigCompEdu and SELFIE for Teachers (European Commission, 2023b), did not gain traction in the UK even before the UK voted to leave the EU - they are sometimes used in UK-specific work (ETF, 2018), though for colleges not schools.

Specific schools provide many examples of success-oriented approaches.

- The *Remote learning policy* at Holmer Church of England Academy sets out minimum provision of academic support, "3 hours a day on average across the cohort for Key Stage (KS) 1, with less for younger children and 4 hours a day for KS2" with completed work to be uploaded to Seesaw (an interactive learning platform for K-5) and learning via Microsoft Teams for both mathematics and literacy (Holmer C of E Academy, 2023).
- In Wales, Broughton Primary School's *Digital Policy 2021-2022* describes

the type of support provided by schools to learners with additional needs: "The school currently provides identified learners with a 1-1 iPad with accessibility features such as Office Lens, Immersive Reader and dictate to create a more inclusive learning experience" (Broughton Primary School, 2021).

School libraries can play a key role in supporting digital learning for students. CILIP (the Library and Information Association) claims that "Digital literacy starts in the school Library" (Hutchinson, 2021). There is no national strategy for school libraries but many municipalities do have a library strategy covering schools (Leeds for Learning, 2023).

Evaluation and analytics

Ofsted, the *Office for Standards in Education, Children's Services and Skills*, oversees the quality of all state-funded schools. It has similar powers over "childcare, local authorities, adoption and fostering agencies, initial teacher training and teacher development" (Ofsted, 2023).

Private schools have a separate inspection system, the *Independent Schools Inspectorate*, authorised by the Department for Education (ISI, 2023) under the *Education and Skills Act 2008* Clause 106 (UK legislation, 2008).

Learning Analytics is the "measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs" (SOLAR, 2023). However, it has come to have a narrower meaning, the use of specific IT systems, using sophisticated mathematical methods to generate insights not obvious from the data.

The EdTech Survey report suggests that "learner analytics" was the fourth most used technology, after whiteboards, computers/tablets and assistive technology (CooperGibsonResearch, 2021, p. 18). The headteachers' survey in the same report claims (in Table 19) that learner analytics is used in 26% of primary schools and 51% of secondary schools (CooperGibsonResearch, 2021, p. 73). In the view of the authors this is implausible except in the widest possible sense of analytics, that is, covering much of what good teachers do routinely.

A search of Google Scholar yields no papers since 2019 about schools in the UK with titles containing the phrase "learning analytics" (or "learner analytics").

Teacher and staff professional development

In 2019 the government's *Realising the potential* strategy stated: "with the Chartered College of Teaching we have launched online training courses for teachers and leaders in education, which strive to improve the use of technology in teaching" (Department for Education, 2019c, p. 16). The first was the FutureLearn course *Using Technology in Evidence-Based Teaching and Learning*, still running (FutureLearn, 2023). In 2023, however:

- The Chartered College does not list any other EdTech courses on its web site (Chartered College of Teaching, 2023).
- The government site *Professional development for teachers and leaders* (Department for Education, 2023i) does not offer any EdTech or ICT courses.
- The FutureLearn course offers just 12 hours of study.

FutureLearn now offers a range of over 20 short courses (at a fee) covering many aspects of digital learning, with in addition some microcredentials and degree-level qualifications (FutureLearn, 2023). However, these longer courses are priced at "market rates" typical of UK university courses, with no evidence of any subsidies for teachers.

There are now many other offerings available to teach teachers to teach in a digital context, although many of them are oriented to teachers in colleges.

One qualification is paradigmatic - *Teaching Teachers to Teach Online*, developed in 2018 to train teachers at virtual schools. Key features were (Online Educa Berlin, 2020):

- **12 credits of study** (a typical amount of study for a university module), not the 2 credits typical of most introductory courses.
- **Taught both pedagogy and practical skills** for digital content development, teaching and assessment.
- **Assessed** via both project-based assignments and a portfolio compatible with CMALT (Association for Learning Technology, 2023a).
- **Accredited** within the England framework for vocational qualifications (Ofqual, 2019) - a "microcredential" (King, 2023).
- **Delivered** via Canvas, one of the four standard VLEs used in UK universities and colleges.

Features of digital learning

There are three features of digital K-12 in England which are not found in many other countries.

1. Homeschooling

In England, *students do not have to attend a face-to-face school*. Parents can "homeschool" their children, in other words, teach them at home with help from online resources or online tutors. This means that there is a market for online content and service provision *direct to parents* in a way different from many other countries.

Officially, homeschooling is called *Elective Home Education* (EHE). The *Education Act 1996* Article 7 states: "The parent of every child of compulsory school age shall cause him to receive efficient full-time education... either by regular attendance at school *or otherwise*." (Department for Education, 1996). This Act confirms a long UK tradition of both home-schooling and virtual attendance at a range of virtual schools - which is officially regarded as home-schooling.

There is no official register of children in homeschooling. There are also no specific legal requirements for the content of home education, "provided the parents are meeting their duty in s.7 of the Education Act 1996" (Department for Education, 2019a, p. 8). Parents are not required to notify any authority if they homeschool their children. In fact, "If a child never attends school, an authority may be unaware that he or she is being home educated" (Department for Education, 2019a, p. 12). Government estimates indicate "86,200 children in elective home education in Spring term 2023" (Education Statistics, 2023a). However, this number may not reflect the true scale of homeschooling.

2. Too wide a range of systems and devices

This brings together points made elsewhere in the chapter.

Teachers in England use over 50 different ICT systems (Gibbons, 2020). Very few schools run one of the four global VLEs used in universities and colleges (Moodle, Canvas, Brightspace or Blackboard) - instead they use less functional offerings, which no post-secondary UK institution would use in a core role for online teaching and learning.

The demands of employers of professionals require a post-secondary institution to ensure that students are competent in Microsoft Office. The vast majority deploy and/or require students to have Windows PCs (a few use Mac computers). In contrast, many schools use low-cost tablets often without keyboards. Chromebooks and Microsoft Surface tablets occupy an intermediate position: low power, less flexible, but low cost and with keyboards useful for Microsoft Office apps. There is no data on the number of schools which require students to use Windows/Mac desktops/laptops.

3. The isolation of digital K-12 in England

Digital K-12 in England is fragmented and isolated, from the university sector (which provides much teacher training), from each other (no central agency or regional aggregation) and from other countries especially in Europe (most EU countries' exam systems are much more compatible with England than the US system is). In more detail, summarising and extending some points made earlier:

1. There is no central agency for ICT in schools. Becta was closed in 2011 - to dismay from experts (Preston, 2010; Selwyn, 2011).
2. There is no regional structure that is effective for digital support or procurement - 150 municipalities is far too many, thus many are too small.
3. Most schools do not use a full-function VLE which universities/colleges use.
4. There is no standard scheme to ensure that teachers have up-to-date skills in using ICT to support teaching. The topic is covered in courses for *new teachers*, but not for teachers already qualified. Few schools are large enough to mount such courses themselves.
5. University/college e-learning staff have the *Association for Learning Technology*, ALT (2023b), which is well known and has considerable traction; however, few school teachers are members.
6. The national inspection system for schools has little focus on ICT. The work from the EU, OECD, and other countries on quality schemes for ICT in schools is little known or used.
7. UK-EU collaboration in education ceased soon after the UK left the EU.

Trends and Issues in Digital Learning

Trends in digital learning

1. Increasing bandwidth to each school and pupil, at school and at home

Bandwidth into schools is increasing each year. Especially during the pandemic, heroic efforts were made to increase it - *London Grid for Learning* (LGfL) upgraded nearly 3,000 schools (Cebr, 2021, p. 10). Yet still, primary schools "were significantly more likely to experience lower bandwidth delivery" (CooperGibsonResearch, 2021, p. 16).

Bandwidth demand, and supply, will continue to grow. The government requires all schools to have full fibre internet by 2025 (Department for Education, 2022f) with performance requirements as follows (Department of Education, 2023k):

- *Primary schools should have a minimum 100Mbps download speed and a minimum of 30Mbps upload speed.*
- *Secondary schools ... should have a connection with the capacity to deliver 1Gbps download and upload speed.*

However, 1 Gbps norm for schools (most less than 1,000 students) will be inadequate for the largest schools (see Table 6). There are three schools with 3,000 or more planned enrolment and several more with over 2,000. Such schools would even today need more than 1 Gbps.

Table 6 Largest Schools in England - Planned and Actual Pupil Numbers

School	Planned #	Actual #
Nottingham Academy	3,570	2,337
Ashfield Comprehensive School	3,146	2,685
Walton High School, Milton Keynes	3,000	2,793

Note. Get Information about Schools, 2023; Open Education Wiki, 2023, Table S.1.

Although virtual reality and augmented reality are used only in a few schools (CooperGibsonResearch, 2021, pp. 72-73), usage will grow, especially for vocational courses in secondary schools, and as Ultra HD video extends into schools.

2. Increasing the number and power of devices used

In the last few years, universities in England recommend students to have a PC laptop. Thus students (or their parents) will have to buy/rent a laptop, in addition to paying £9,250 annually for university study. This financial approach is not an easy option for state schools with zero fees, but there are signs that some schools can now fund provision from state funds or donations (see Issue 3 on "the role of parents").

Currently, few face-to-face schools have a device:student ratio of 1:1 - a typical ratio is 1:4 (CooperGibsonResearch, 2021, p. 18) and most devices are not PCs, yet.

3. Exams remain paper-based

A levels are the exams used by universities to select students for higher education courses; GCSEs are used by schools to select who is best placed to benefit from A levels and by organisations to select for employment including apprenticeships.

England shares a common approach to GCSEs and A levels with Wales and

Northern Ireland, using four different exam boards. The exam boards operate as part of a hierarchy (Ofqual, 2020):

- The Department for Education sets the subject details that GCSEs and A levels must cover.
- Ofqual regulates qualifications, deciding which organisations can offer GCSEs and A levels, and sets rules that exam boards must follow.
- Exam boards develop, mark and award GCSEs and A levels, working in association to ensure common policies.
- Schools are responsible for teaching and learning, preparing students to take the qualifications and providing support after the results.

The exams are undertaken in a supervised situation, normally an exam centre at a specific time and date. Most subjects have two or three exams; some subjects grade coursework done at school. Most exams *require students to handwrite all their answers, including essays* - in fact, laptops are allowed mainly when some disability precludes handwriting (Think Student, 2022) rather than for all exams, as would seem natural in a digital world.

During the pandemic, exams were cancelled, students were awarded grades based on teacher predictions, and universities, employers and parents agonised over standards (Kippin & Cairney, 2022). This led to pressure for digital assessment - for many prior years there had been little interest in this (Mansell, 2009). Covid provided the stimulus - but researchers had already researched the issues and vendors gained experience in other countries.

In 2022 Ofqual announced a review of "whether greater use of technology in assessment and qualifications could deliver benefits for students and apprentices" and specifically mentioned "remote invigilation" (Education Hub, 2022). One exam board (AQA) also carried out research (Whittaker, 2022). Their full report was generally more positive than the cited article but flagged the need to upgrade school infrastructure and ensure home access. A forward-looking conclusion was that such work should "enable the next wave of school development, allowing students to experience a rich curriculum while also preparing for its application in a digital world" - but there was a key caveat, that the initiative's success "relies upon on a government-led programme of national change" (AQA, 2022).

In summer 2023 Ofqual confirmed a study of the feasibility of "fully digital" exams (ParliamentLive TV, 2023).

4. Virtual schools growing but still peripheral

Virtual schools first appeared in the United States. Hence an early definition is US-oriented: "an entity approved by a state or governing body that offers courses through distance delivery - most commonly using the Internet" (Barbour & Reeves, 2009).

In England, a virtual school often means something different - "a statutory service which exists to promote high aspirations for our children placed in care and previously looked after" (Worcestershire County Council, 2022) - correctly called a *Virtual School for Looked-After Children* (VSLAC). This normally uses teachers from several schools to teach such children - the virtuality is in the structure of the school, not in the *method of delivery*.

Virtual schools in the US sense started in the UK in 2005, when Interhigh was founded to teach online (King's Interhigh, 2005). Earlier, in 1963 the National Extension College started as a correspondence college - this began a move to blended provision (with some online) around 2000 (NEC, 2023).

There is currently no official data on the number of virtual schools or the number of students who are studying at them in England. The Department for Education is reported as estimating "25 online education providers" (Martin, 2023). All are private schools. Table 7 shows some virtual schools operating from England.

Table 7 Virtual Schools in England

Virtual School	Ages	GCSE	A level	VLE
Kings Interhigh	7-18	Y	Y	Canvas
Harrow Online School	16-18	-	Y	-
My Online Schooling	7-18	Y	Y	Canvas
National Extension College	16-18	Y	Y	Moodle
Oxford Homeschooling	11-18	Y	Y	Moodle
Wolsey Hall	5-18	Y	Y	Canvas

Note. Lloyd, 2023; Open Education Wiki, 2023, Table V.1.

In addition to virtual schools offering the full range of schooling, there are other online providers in the UK who offer online tuition, GCSE or A level courses to adult students, resources to support homeschooling children and their parents, and US-style or international K-12 qualifications.

There was until 2023 no accreditation system for virtual schools (Department for Education, 2023e). The indicators for the scheme (Department for Education, 2023f) mainly ensure that the virtual school can be accredited as a school on the official list (Get Information about Schools, 2023) - there are only a few indicators on teaching and just one (2.6) on use of digital resources (Department for Education, 2023f, p. 15).

Virtual schools depend on computer hardware and internet for students at home. They require a PC-style laptop or desktop PC (not tablets or smartphones) plus a reliable broadband connection. They focus on reliability - tending to favour cloud-based, established systems from larger suppliers.

5. Increasing role for centralised and open content

Open Educational Resources (OER) are "learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, that permit no-cost access, re-use, re-purpose, adaptation and redistribution by others" (UNESCO, 2019, p. 2). England never had a K-12 OER policy and never funded any OER K-12 repositories, surprising since there was a large government-funded OER programme for universities in 2009-2012 (McGill, 2014).

Despite the universities OER project, most municipalities overseeing K-12 paid little attention to OER - excepting one where an OER expert had a senior role from 2010-16 (Fraser, 2015) - nevertheless just one school in that municipality still has a public OER policy (Rushey Mead Primary School, 2021).

There has been no central overall repository of digital K-12 content, OER or not. Specific collections popular in recent years include:

- Wikipedia (English) with over 6.7 million articles (Wikipedia, 2023c)
- Free image libraries such as Wikimedia and Flickr
- OpenLearn, from the Open University, with many free courses relevant to K-12
- TES Resources, with over 900,000 resources (TES, 2023), some free, others via schools subscription
- Pearson resources for teachers including free examWizard (Pearson, 2023a)
- Khan Academy - free online lessons and pioneering AI tools.

Subject teachers usually have access to specific collections or tools. These may come from (taking Latin as an example): universities (University of Warwick, 2023), subject teacher associations (ARLT, 2023) or specific government-funded projects (Centre for Latin Excellence, 2023) (Oak National Academy, 2023b).

One theoretical advantage of teaching in England is that there are open resources in other English-speaking countries - however, there is no evidence that teachers in England use Scottish resources or open content from MERLOT and other US K-12 repositories. One barrier to use may be the lack of categorisation of non-England teaching resources by the subjects and levels used in England.

One feature familiar to universities who use modern VLEs is the ability to share *whole courses* and import courses which are openly licensed. Canvas allows all users access to Canvas Commons, its sharing platform; Moodle has something similar, Moodle.net. There is no evidence that course sharing of this sort happens in schools, unlike universities.

The key issue that came to the fore in the pandemic was the lack of *free* (or easily licensable) relevant content. The content did exist - many virtual schools and online K-12 providers had most subjects available online in both self-study and tutored form. Yet, government did not seem to want to license access to such material; instead it set up a new provider, *Oak National Academy*. This led to long delays in creating a critical mass of data, with large gaps (Martin, 2022) at the start of the 2022-23 school year.

After reflecting on the needs demonstrated very visibly during the pandemic, the government came to the view there was again a national need for a central repository, not one with a wide remit like Becta, but with a specific remit to provide online learning resources for the National Curriculum. A Full Business Case was published in October 2022 - the core analysis states (Department for Education, 2022c, p. 6):

> *... two main curriculum problems exist:* ***weaknesses in curriculum design and delivery,*** *...; and* ***excessive teacher workload associated with curriculum planning. ... have been exacerbated by the pandemic***
>
> *... the key causes of these problems are that teachers are under-supported in the curriculum resources they have access to ... due to one or more of:* ***lack of buy-in to the value of full curriculum resources; lack of confidence in***

> ***the quality of the curriculum resources currently available****; and* ***difficulty in accessing and using high quality curriculum resources****.*

The consultations leading up to this policy caused the usual backlash from teachers (Martin, 2022), unions, and content developers (Publishers Association, 2022) - and even some of the original Oak partners (Coles, 2022). There were the usual issues over teacher autonomy (NATE, 2023). Nevertheless, the National Academy is going ahead.

Issues in digital learning

The "issues" discussed below have in common that there is no obvious consensus solution. Where feasible, some suggestions are given.

1. Continued structural disorganisation in the school sector

The wide variety of ICT systems used in schools leads to problems with support, training and resource sharing. The structural issues within the sector and the lack of group action do not help.

Some progress is being made. The Department for Education now has an effective regional structure based on the Government Regions, but still no regional component to handle digital issues. Academy Trusts play an increasing role in overseeing their schools, but many local education authorities do not manage digital strategy for their schools. In fact, a high percentage of both primary and secondary schools have no strategy or *school-specific* strategies - making group procurement hard or impossible (CooperGibsonResearch, 2021, pp. 76-77).

There are still around 5,000 small primary schools (enrolment under 200 students) (Weale, 2019) - unviable for an autonomous ICT strategy.

This situation leads to fragmented procurement, leading to no economies of scale or free added value services such as training. In contrast, UK colleges and universities have a more centralised/ regionalised/ group-oriented approach to procurement, which leads to a much smaller range of systems, and better support for these.

2. Signs of convergence in Sixth Form Colleges for DL

Sixth Form Colleges are set up to teach only A levels and equivalent vocational qualifications such as T-levels. Some of them were until recently in the FE College sector. This means that they teach subjects at levels which in some other countries (including Scotland and Canada) are taught at first year in universities. Initial information suggests that this is leading to a more university-like approach to systems, which may lead in time to convergence with post-secondary in ICT terms. Table 8 is a partial listing of Sixth Form providers with global VLEs (see Table 8).

Table 8 State Sixth Form Providers and the University-style VLEs They Use

State schools	Type of state school	VLE
AbbeyGate Sixth Form College	Free School	Moodle
Ashton Sixth Form College	Academy	Canvas
Beverley High School	Local Authority School	Moodle
Blue Coat Church of England School and Music College	Academy	Moodle
Chester International School	Studio School	Canvas
Salford City College Group	Academy Trust	Canvas
St Mary Redcliffe and Temple School	Voluntary Aided School (Faith School)	Moodle

Note. Open Education Wiki, 2023, Table L.1.

The Sixth Form Colleges Association (SFCA), representing the 110 Sixth Form providers in England and Wales (SFCA, 2023b), makes a key point about flexible learning and VLEs in its strategy development paper (SFCA, 2023a):

> *sixth form colleges ... realise that students are more likely to be successful when they have* ***independent, critical thinking skills****, and are therefore conscious of how their digital strategy,* ***including a virtual learning environment*** *(VLE), can facilitate this*

In terms of staff development, software platforms compatible with universities and colleges would facilitate the construction of teacher training courses by universities-schools consortia and of self-study or tutored courses for A level subjects, and, importantly, their use by teachers and students, as the systems would be more familiar and transfer of content simpler.

For device aspects see below.

3. Unclear role of home and parents in DL

There are a number of home- and parent-related areas in digital K-12 where there is a long-standing reluctance of government to confront key issues. The main ones are:

- Homework, with the vagueness over the value and amount - discussed earlier.
- A reluctance to monitor homeschooling (discussed earlier) and the challenge of children not in school. After the pandemic, the Children's Commissioner (2022) revealed "tens of thousands of children who are persistently or severely absent or missing from education altogether".
- Vagueness about whether government, municipalities, schools or parents will fund the "one laptop per child plus broadband" needed at home to make ICT in schools really work. This is in addition to the laptops or desktops needed within each school.

There is no recent published research on the extent to which 1:1 access to a suitable device (tablet or laptop) has been achieved - but initial indications (see the Table below) are that a small but steadily increasing set of schools of all types are doing this, for some age groups (see Table 9).

Table 9 A Small Selection of Schools with 1:1 Provision of Devices

School	Type	Devices	Reference
Ark Schools	Academy Trust: 40 schools	Chromebook laptops	"a Google Chromebook from year 3, together with access to … 'Office 365' applications from ... whatever device they are using" (Ark Acton, 2023)
Oldham Sixth Form College	Academy 16-19 Pinnacle Trust)	Chromebook laptops	(OSFC, 2023)
Eton	Private: boys Very high fees	iPads	(Eton, 2023)
Wycombe Abbey School	Private: girls High fees	MS Surface laptops	(Wycombe Abbey, 2021)
Manchester Grammar	Private: boys Medium fees	MS Surface laptops	(Whitear, 2021)
Birkdale School	Private Medium fees	Chromebook laptops	(Birkdale School, 2023)

The examples of the Ark Schools Trust and Oldham College show what can be done within state school budgets, suggesting that the key constraints are motivation not finance. An iPad can be leased and supported for £120 per year (KRCS, 2023), within the overall framework set by the government (Department for Education, 2023b).

However, there are few signs yet of any schools adopting a PC laptop policy for pupils.

4. Unwillingness to change the school day or year to support DL

There is no evidence of any schools in England adopting a significantly different length of or pattern to the school day because of blended learning. The school week in England is defined as a "a 32.5-hour week" - an average 6.5-hour day (The Key Leaders, 2023). The length of a school day is "tightly distributed" between schools (Long, 2023, p. 17). There have been years of discussion on the benefits of a *longer* school day - in contrast, there is little discussion of the benefits of a *shorter* school day (Juni Learning, 2023) facilitated by DL.

There is an approach, "study leave", which allows older children to stay at home while studying for exams (Nash, 2023), when they could use online resources. However, this approach does not apply during days when teaching takes place at school.

In England, local authority-maintained schools have to open for at least 190 days in the school year (Long, 2023, p. 4). Tradition and parental expectations mean that schools all divide the school year into three terms with similar dates. There are discussions about changing school terms: in particular, the summer holiday is felt by educators to be too long. During the end-phases of the pandemic, suggestions were made for "longer school days and shorter holidays" to help students overcome the learning gap that Covid produced - these led to strong fight-back from teachers (Miller, 2021) and were never implemented.

5. Use of artificial intelligence and other advanced technologies in schools

Few schools use any artificial intelligence or virtual/augmented reality technologies (CooperGibsonResearch, 2021, p. 18). Yet, such technologies, along with Robotics and Blockchain, are seen by futurists, in the Future Opportunities report (Vicentini et al., 2022, p. 26) as soon to be deployed operationally, not just as experiments.

Artificial intelligence

In the 2023-24 school year, artificial intelligence - mainly via language model tools such as ChatGPT - will continue to integrate into school-level education. This includes the use of tools by both teachers and students alike. In the 2022-23 school year, teachers in many schools were discussing the issues surrounding AI and how it would impact on assessment, both in-school and high-stakes national (GCSE and A levels). The government released initial guidance in March 2023 (Department for Education, 2023g) along with detailed guidance from the Joint Council for Qualifications (2023). Later, the government issued a *Call for Evidence* to further inform their future policy development (Department for Education, 2023a). The *Teacher Development Trust* (2023) has produced a guidance document with comprehensive information.

The view from K-12 experts, such as Professor Mike Sharples, who led the Becta CAPITAL project, is that such tools "should be used to enhance pedagogy, rather than accelerating an ongoing arms race between increasingly sophisticated fraudsters and fraud detectors" (Sharples, 2022). However, there are likely to be a few "difficult" years for AI in schools in the immediate future, reminiscent of when pocket calculators arrived (Watters, 2015).

Blockchain

In contrast, blockchain, though featuring strongly in recent research (Vicentini et al., 2022) is in the view of the authors not likely to be directly relevant to the schools sector for some years. Blockchain has become an EU priority (European Commission, 2023a), in particular to underpin a new model of modular qualifications - *microcredentials* (European Education Area, 2022). However, England already has a long-standing *well-developed* microcredentials system (Ofqual, 2023).

Robots

Robots bring together both the advantages and the costs of augmented reality and artificial intelligence. Some thoughtful meta-analyses have been published (Karim et al., 2015). However, there is also a great deal of hype which confuses autonomous robots with passive devices which are stands holding a camera, screen and microphone. Press reports such as *AV Robots helps children stay in school* (Warwickshire County Council, 2023) seem unaware of the many hospital schools supporting pupils with standard online tools (Sheffield Teaching Hospitals Trust, 2023).

Virtual reality and augmented reality

VAR, in other words, Virtual/Augmented Reality, is slowly being deployed in schools (CooperGibsonResearch, 2021, p. 130), Table 52 - despite one meta-analysis (Lou et al., 2021) noting that "Research findings on VR-based education have been conditional and inconclusive." VAR makes substantial power and thus cost demands on both devices and networks and is likely to appear first in vocational training and university teaching before widespread use in schools.

Conclusion

This chapter reviews the current state of digital K-12 in the United Kingdom with emphasis on England. It paints a picture of digital schools giving evidence to substantiate the UK's high ranking in digital maturity studies and analyses.

The chapter begins by summarising the K-12 system in England and the factors of the National Curriculum and National Exams which produce a uniform system despite the wide variety in size, purpose, organisation and funding of schools.

It describes the policy interventions, funding schemes, large-scale projects and influential reports in the 18-year period 2005-23, demonstrating that decisions taken more than ten years ago have continuing effects today, and that the pandemic rapidly accelerated existing trends rather than setting a brand new direction.

A broad view is taken of infrastructure covering technology, leadership, budgets, course design/delivery, ensuring student success, staff development, quality and inspection, and analytics. It provides data and examples for the main trends analysed - bandwidth, school networks, software, end-user devices, and content.

It covers topics often omitted in such reports, such as private schools, homeschooling, virtual schools, open content, online national examinations and the overlap of K-12 with the post-secondary sector.

It reviews key issues: structural disorganisation leading to fragmented procurement of a plethora of systems, the multi-dimensional isolation of K-12 including the disconnect between school and post-secondary digital approaches and systems, lack of clarity on the role of parents, the rigidity of the school day/week/year limiting the scope for blended digital learning, and the promise but problems of advanced technologies.

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Trends and Issues of Digital Learning in the United States of America

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Abstract

The U.S. education system is overseen by a federal Department of Education, but each locality and state has a level of autonomy to determine how curricula are implemented for their specific group of learners. Digital transformation and equity in digital learning are cornerstones of United States K-12 education, and the federal Department of Education provides oversight and financial assistance to school systems to assist in providing digital learning artifacts. U.S. public school education has a strong background in ensuring students have access to technology tools to assist learning by either classroom technology use of 1:1 device programs. The U.S. public education system is in the digitalization stage for most of its levels except for early childhood which is still at the digitization stage due to recommended restrictions on early learner technology use. Personalization of learning experiences, use of gaming applications to promote engaged learning, e-texts and interactive textbooks are the primary digital tools employed for engaged learning. U.S. education also has a strong presence in data-driven decision making using digital tools to assess learner progress, individualize instruction, and provide data to the federal Department of Education for funding purposes. During the COVID-19 pandemic, U.S. education was catapulted into a major shift of online learning which brought to the forefront disparities in connectivity for rural areas of the country. The changes initiated by the global pandemic saw implementation of new digital tools to assist learners, and most are still in use today. Infrastructure, professional development, and the digital divide, including the newer terminology of digital use divide are noted as major issues in ensuring all learners receive equity in their digital learning experiences. U.S. K-12 education is focused on providing increased access and opportunity for all learners by enhancing its infrastructure and digital transformation for global learning opportunities.

Keywords: digital learning, digital divide, K-12 education, artificial intelligence, infrastructure

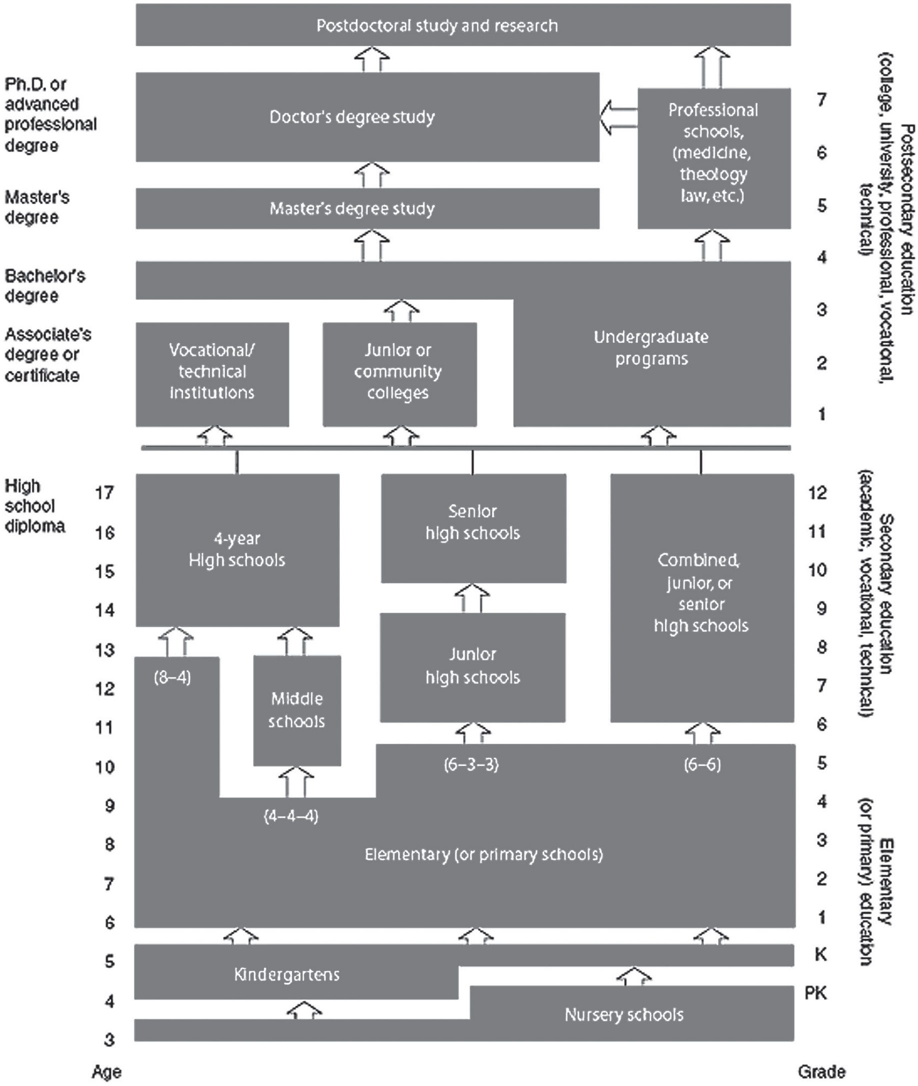
Introduction

Structure of the educational system in the United States

The United States (U.S.) utilizes a comprehensive pattern of schooling. It encompasses early childhood education (called elementary schools in the U.S.), middle school (or middle level education), secondary education (high or senior high schools) and the tertiary level of education denoted as postsecondary education. Post-secondary education can include non-degree programs leading to career studies certificates, general education certificates, or a diploma. There are also six different categorized degree levels including associate, bachelor, first professional, master, advanced intermediate, and research doctorate. The U.S. does not offer a second or higher achievement level doctorate, but does have post doctorate opportunities to continue in research programs. The U.S. system also offers numerous adult and continuing education opportunities, often denoted as workforce training or learning, as well as special education programs throughout many of the educational levels (U.S. Department of Education, 2008). Figure 1 below provides an overview of the U.S. educational system structure.

U.S. education benchmark performance to peer countries shows that U.S. scored in the top 25% of participating systems in mathematics and science at 4th- and 8th-grade levels as reported by the 2019 Trends in International Mathematics and Science Study (TIMMS) (Irwin et al., 2023). Irwin et al. reported "92% of 25-64-year-olds have completed a high school degree, the United States was among the top 6 out of 36 countries in 2021 reporting data…to the Organization of Economic Cooperation and Development" (p. 40).

Figure 1 The Structure of Education in the United States



Note. U.S. Department of Education, National Center for Education Statistics https://nces.ed.gov/programs/digest/d01/fig1.asp

The U.S. education system has a national department of education to provide oversight, yet the system does not have a centralized model of regulation, but a very decentralized one that allows for a wide variety of regulations, laws, court decisions, and local policies to define educational systems. Each locality, be it a city or a county in a state, has oversight in how, when, and why educational programs are offered. Each state department of education has oversight to ensure there is a modicum of continuity in providing federally mandated framework laws. According to the U.S. Department of Education (2021), establishment of schools, curricula, enrollment and graduation requirements are primarily a responsibility shared by each state and its localities.

The U.S. Department of Education oversight provides important policy leadership for states which in turn provide policy and leadership for localities (U.S. Department of Education, 2021). The U.S. Department of Education also provides minimal monetary support, approximately 8% of the $1.15 trillion spent nationwide on all levels of education. These funds come from the Department of Education, but also include other federal departments such as Health and Human Services, the Head Start program, and the school lunch program from the Department of Agriculture (U.S. Department of Education, 2021). In the U.S., the White House ensures the citizenry is apprised of Presidential activities and initiatives related to education in conjunction with the U.S. House of Representatives Committee on Education and Labor, which provides information on legislative bills, hearings, testimonies or other actions pertaining to education. The U.S. Department of Education states its goal has remained the same over the years since its inception in 1867 which is "to promote student achievement and preparation for global competitiveness [emphasis added] by fostering educational excellence and ensuring equal access [emphasis added]" (para. 10).

Global competitiveness and equal access are critical components of digital learning. The U.S. education system experienced an unforeseen awakening when the pandemic, COVID-19, hit all schools, businesses, and communities, forcing complete shutdowns of most businesses, and requiring the use of virtual learning for all levels of education. The pandemic brought to the forefront the fragmented relationship between U.S. education systems and our current infrastructure. The Center for Digital Government survey (2022) highlighted that states agree that among other top priorities such as cybersecurity and modernization of legacy technologies, an important priority is increasing "broadband/connectivity/addressing the digital divide" (Government Technology, para. 4). The digital divide issue is widespread throughout the U.S. and a cause for concern related to digital transformation (Dx) in this country.

Digital transformation (DX) in U.S. K-12 schools

Digital Learning (DL) revolves around the ability to exercise a level of control of learning time and place by using blended or virtual modalities through various mobile technologies and systems. DL is also a key construct of successful digital transformation. The U.S. has made progress in expanding access to technologies through federally supported initiatives and projects. Statistically, 90% of all U.S. schools report at minimum one computer for every five students, and 98% of classrooms have internet access (Baruffati, 2023). Yet, there is still a digital divide across the country with many areas, especially rural, remote areas, having very limited access to broadband internet, along with the financial divide of those who cannot afford the technologies to undertake digital learning. The following paragraphs provide an overview of the digital transformation in the United States.

ISCED level 0--early childhood: Birth to age 2

The U.S. education system does not have a formal educational setting for early learners aged from birth to age 2. It does, however, address this stage of learning and digital usage considerations in its policy brief (Office of Educational Technology, 2016). Digital transformation at this educational level is limited due to age restrictions supported by the American Academy of Pediatrics (AAP) 2016 Media and Young Minds Brief recommending appropriate technology usage, of one hour daily inclusive of home, early learning settings, and across multiple devices (Office of Educational Technology, 2016). Due to limited technology use in educational settings but more widespread use in educational recordkeeping, this level of the U.S. educational system is at stage one, or digitization.

ISCED level 1--lower primary

This level in the U.S. education systems encompasses two distinct groups – lower primary (elementary) education and upper primary (elementary), broken into segments of Prekindergarten through grade 2 and grades 3 through 5 (although some systems include grade 6 in upper primary). The U.S. system of education places a strong focus on early childhood education as supported by many federal programs encouraging children to begin school as early as age 3 or younger if the learner has special educational requirements. Learners have opportunities to use technology in simpler forms, but this usage is guided and overseen by the educators. AAP again recommends one hour of technology use as appropriate for this age grouping. In addition to limiting technology time, it is important to ensure the quality of content, and how technology is used in the educational setting. Both the teachers and the family ideally monitor these constraints to ensure these early learners still have opportunities for free, creative play.

The administrative side of this level of learning does employ numerous technology database tools for reporting and recordkeeping purposes. Data collection of students enrolled, their time spent in formal classrooms, along with educational resources provided to these learners, assists the U.S. in serving these early learners and providing needed resources based on socioeconomic, racial/ethnic, and linguistic data. As stated previously, the U.S. does not have a national education system, but each individual educational system reports data to their state departments and are awarded funding based on these metrics.

For the lower level of primary education, the U.S. system is in the digitization stage.

ISCED level 1--upper primary

For the upper level of primary education in the U.S., ages 6 through 8, grades 3 through 5, this level has a more intentional integration of technology into the learning program, but is used in conjunction with academic materials such as art, writing, play, books, and "should give learners an opportunity for self-expression" (Office of Educational Technology, 2016, p. 8). The National Association for the Education of Young Children (NAEYC) and the Fred Rogers Center (2012) state, "technology and interactive media should be used in ways that support existing classroom developmental and educational goals rather than in ways that distort or replace them" (p. 8). This position paper further supports that technology usage should not "replace paints, markers, crayons, and other graphic art materials but should provide additional options for self-expression" (p. 8). For these grade levels of primary education, the U.S. is straddling the stages between digitization and digitalization as more investment is made in provisioning of technology equipment, professional development and training of educators, and technical support.

ISCED level 2--lower secondary education

In the U.S., the level considered lower secondary education is typically grade levels 6 through 8, characteristically ages 9-13. Learners in this level are subject to more locality and state mandated testing due in part to national educational standards such as the Common Core (CC) and state mandated standards such as end-of-course (EOC) or standards of learning (SOL). Common Core standards were enacted in 2010 to provide continuity for students, grades K-12, in their educational achievements if they moved from one school district to another, or to another state. Initially embraced by all but four states in the U.S., recently these standards have been repealed by more than 20 states due to testing controversies (Goldstein, 2021). The testing occurs online, and therefore there is a more intentional use of technology through the online learning process via gaming, scenarios, and guided practice, along with local benchmark or point in time testing prior to the mandated testing. Lower secondary education is at the digitalization stage as the school systems invest more in training for educators and make use of more digital processes to enhance the learning opportunities for the learners.

ISCED level 3--upper secondary education

Upper secondary education is considered to be grades 9 through 12, traditionally called high schools, with learners aged 14 to the upper limit age of 20 or 21 (after 21 students are referred to adult education centers). Learners in this level are again assessed in multiple courses with some assessments presenting barriers to graduation if passing scores are not earned. Students typically take eight core subjects of English, mathematics, social studies, and science, along with elective coursework during their four years of high school education. Students are offered a variety of electives such as visual arts, career and technical education (CTE), or honors classes for academically gifted students. Students must earn a total of 30 credits to graduate from their core and elective coursework. Students in upper secondary have multiple opportunities to utilize technology in their course work via simulations for business or CTE courses such as computer applications, Computer Aided Design, and in their core academic classes using technology-enhanced lessons in sciences, mathematics, and English. The upper secondary level of education in the U.S. is still at the digitalization stage.

The Status of Digital Learning

Digital learning has been gradually increasing in the U.S., but experienced huge growth during the COVID-19 pandemic years of 2020-2022. Digital learning began in the early 1990s and was generally referred to as "K-12 online and blended instruction" (Black et al., 2020, p. 119). According to the National Center for Education Statistics (2019), in 2017-18, 27% of all public schools offered courses online. Yet digital learning is more than online coursework as it encompasses access to technology, robust internet connectivity, and digital curricula. The U.S. government enacted Title IV Part A authorized under the Elementary and Secondary Act (ESEA 1965) as amended by the Every Student Succeeds Act (2015) to promote overall academic achievement for all students. This act provided more power to U.S. states, local education agencies (LEAs), and schools to "(1) provide all students with access to a well-rounded education, (2) improve school conditions for student learning, and (3) improve the use of technology to improve the academic achievement and digital literacy of all students" (T4PA Center, n.d., para. 1). Part A of the act provided monetary support, $400 million to $1.17 billion (2017-2019) (para. 4), to achieve these goals. Specifically, goal three mandates activities to support the effective use of technology focused on increased professional development for school personnel, specifically educators, building infrastructure and technological capacity, effective or innovative strategies for academic content delivery using technology, and providing enhanced access to educational opportunities for those in rural, remote, and underserved area (T4PA, n.d.; National Association of Secondary School Principals, n.d.). Local school districts and LEAs receive money with restrictions that no more than 15% of their allocation may be spent on purchasing technology infrastructure including devices, software, and peripheral equipment (National Association of Secondary School Principals, n.d.).

Contexts of digital learning (DL)

Digital learning covers many aspects of the educational environment from individualized instruction to classroom collaborations. Gillpatrick emphasizes that "the pace of change brought about by digitization is fundamental and transformational for education" (2020, p. 195). The U.S. Department of Education is promoting the need for these changes to ensure equity in education and accessibility for learners (Office of Educational Technology, 2017). In the United States, digital learning is a main priority and is offered in many modalities dependent upon the location, funding, and accessibility to broadband services for K-12 schools nationwide. The Office of Educational Technology (2017) provides "a national vision and plan for learning enabled by technology" (p. 3) for all educational stakeholders, including but not limited to researchers, school district leaders, entrepreneurs, and nonprofit organizations. This plan is not mandated as each state and locality have certain levels of autonomy, but compliance is recommended to ensure all learners are afforded the best educational opportunities possible. Nationally, K-12 schools are tasked with developing a vision and a workable plan to ensure all learners achieve their educational goals through the intentional use of digital learning technologies. The plan, the National Educational Technology Plan (NETP), challenges educational systems to ensure a robust infrastructure which must include digital learning content, assessments, as well as professional development for educators and education leaders. In the U.S. Department of Education's *Fast Response Survey: Use of Educational Technology for Instruction*, schools nationally reported that digital learning helped students be more independent and self-directed (33%), while 41% reported that it promoted engagement in more active learning, and it also allowed students to learn at their own pace, reported at 35% (Gray & Lewis, 2021).

Digital learning policies, projects/programs, strategies, and research and development

As outlined in the status of digital learning, Title IV, Part A of the Every Student Succeeds Act (ESSA) of 2015 was developed to improve overall student academic achievement. The U.S. government provided funding for this program in three major areas: (a) well-rounded educational opportunities with a minimum of 20% of school allocation expended, (b) safe and healthy students with a minimum of 20% of allocation expended, and (c) technology and digital literacy with no more than 15% of allocation used for technology infrastructure (National Center for Safe Supportive Learning Environments, n.d.). This government act specifically defines "blended learning as a formal education program that leverages both technology-based and face-to-face instructional approaches" (National Center for Safe Supportive Learning Environment, n.d., Section 4102 [20 U.S.C. 7112]) and digital learning as:

> any instructional practice that effectively uses technology to strengthen a student's learning experiences and encompasses a wide spectrum of tools, practices, including –
>
> (A) interactive learning resources, digital learning content (which may include openly licensed content), software, or simulations, which engage students in academic content;
>
> (B) access to online databases and other primary source documents;
>
> (C) the use of data and information to personalize learning and provide targeted supplementary instruction;
>
> (D) online and computer-based assessments;
>
> (E) learning environments that allow for rich collaboration and communication, which may include student collaboration with content experts and peers;
>
> (F) hybrid or blended learning, which occurs under direct instructor supervision at a school or other location away from home and, at least

in part, through online delivery of instruction with some element of student control over time, place, path, or pace; and

(G) access to online course opportunities for students in rural or remote areas (National Center for Safe Supportive Learning Environment, n.d., Section 4102 [20 U.S.C. 7112]).

This specificity is key to ensuring that government funding is allocated to school systems and LEAs for digital learning. This act also encourages the concept that this funding is to supplement, not supplant, non-Federal funds that are allocated for digital learning initiatives (National Center for Safe Supportive Learning Environment, n.d.).

The National Educational Technology Plan (NETP) is considered the flagship educational technology policy for the U.S., and works in tandem with the federal policy of ESSA, Title IV, Part A. The overarching communication of the policy is to ensure equity for all stakeholders, active use by educational entities, and collaborative leadership. The plan promotes the need for all "in American education to ensure equity of access to transformational learning experiences enabled by technology" (Office of Educational Technology, n.d., para. 2). According to the National Education Technology Plan (2017), the precepts and principles detailed in its NETP align to federal legislation in Title IV A, which is a part of the Elementary and Secondary Education Act of 1965 (ESEA), which was amended by the Every Student Succeeds Act (ESSA) in 2015. The U.S. Department of Education, Office of Educational Research and Improvement, in conjunction with the National Center for Education Statistics, published recommendations and guidelines for technology in schools in 2002. The intent of this document is to assist school districts, which operate independently yet receive federal funding for initiatives, in understanding all the nuances needed for transformational educational learning. The National Center for Education Statistics (NCES) (n.d.) provides a *Forum Unified Educational Technology Suite* assimilating various educational reports from the U.S.

Department of Education, IES, and NCES. This site and provided documents are designed to provide updated resources for individual school systems, and presents a "practical, comprehensive, and tested approach to assessing, acquiring, instituting, managing, securing, and using technology in education settings" (NCES, n.d., para. 11) to ensure understanding of all local, state, and federal requirements for digital literacy for student academic advancement.

Research and development for digital literacy in the U.S. is driven by government support and funding through various national centers. Their mission is "to contribute to the production and dissemination of rigorous evidence and products that provide practical solutions to important education problems" in the U.S. (U.S. Department of Education, National Center for Education Research, n.d., para. 1). The U.S. Department of Education supports numerous active (13) and completed (21) R&D centers including The National Center for Rural Education Research Networks (NCRERN), the National Center for Research on Gifted Education, Postsecondary Teaching with Technology Collaborative, and the National Research and Development Center on Instructional Technology: Center for Advanced Technology in Schools (completed) (U.S. Department of Education, National Center for Education Research, n.d., paras. 2 & 3). The newest R&D center is *Precision Education: The Virtual Learning Lab*, which has a focus on personalizing and improving virtual learning. It will utilize data from prior students to support learning opportunities for students in future learning environments.

DL implementation in K-12 schools

Digital learning implementation in U.S. K-12 school is an on-going process, especially during the past decade with increased government support. Nationwide there are varying levels of adoption and integration into the schools and curricula specifically due to vast discrepancies in funding from local educational systems, internet connectivity issues, and geographic divides, which make integration for larger groups of students difficult in certain midwestern sections of the United States.

The Office of Educational Technology (OET) provides policies and vision statements regarding digital inclusion, ecosystems, and emerging trends and technologies for all school systems to guide their efforts for successful digital learning.

Early childhood education

The U.S. Department of Education, Office of Educational Technology (2016), set forth four guiding principles for early learners and technology usage.

> Guiding Principle #1: Technology - when used appropriately – can be a tool for learning.
> Guiding Principle #2: Technology should be used to increase access to learning opportunities for all children.
> Guiding Principle #3: Technology may be used to strengthen relationships among parents, families, early educators, and young children.
> Guiding Principle #4: Technology is more effective for learning when adults and peers interact or co-view with young children (p. 7)

These principles support early limited technology use for young learners and emphasize the need for "unstructured, unplugged, interactive, and creative play" (Office of Educational Technology, 2017, p. 13). The early learning school environment and its educators, therefore, do not integrate multiple technology approaches in their learning routines, but do utilize technology for the recordkeeping and business functions of the system.

Primary education – lower and upper

Lower elementary learners from ages 2 through 5 are the entrance level for lower elementary education. This group adheres to the same guiding principles as listed above for level 0. In 2020, about 55% of 3- to 5-year-olds were enrolled in schools, with enrollment higher for 5-year-old learners than for 3- to 4-year-olds (Irvin et al., 2022).

In the upper elementary age group, 6 through 8, one must consider whether the technology extends the learning opportunities for all learners in ways that traditional educational methods cannot. Careful consideration of content, context, and individual learners should drive the use of technology at this age (Guernsey, 2012). This level of learners requires a strong focus on ensuring technology use does not distract from teacher and peer interactions, nor does it employ features that distract from learning in general. Guiding principle #2 reinforces how technology can support STEM in early learning situations utilizing social interactions and guidance from educators, along with video and games, to increase mathematical skills and computational thinking. This age of learners is ideal for learning mastery of technology artifacts and learning how to create content, that is, be producers, of technology-based information (NAEYC, n.d.).

Grades 4 and 5 in upper primary employ more learner-based technologies as some activities used to engage learners are in a digital format, yet the time spent with technology is monitored for learners in this group. The administrative side is heavily invested in digitalization as the reporting requirements for this age of learners are more structured and mandated by government testing and recording processes.

Lower secondary education

Learners in this level are given more opportunities to choose some of their subject content and have opportunities to take more elective courses including arts, music, and technology-based courses. Learners in middle level education use technology in most of their courses in many different modalities including laptops, tablets, and mobile devices such as smart phones. Pew Research (2013) reported that “45% … use e-readers and 43% use tablet computers in the classroom or to complete assignments" (Purcell et al., p. 2). As this research is 10 years old, it is believed that the number has increased significantly. It also stated that most educators use digital tools to assist students in conducting research online. Learners in both lower and upper secondary education often use a learning management system (LMS) that assists the school in delivering digital content, organizes the course materials and ancillary resources, and provides a digital means of secure communication between the students and the teachers.

Upper secondary education

Learners at the upper secondary level are afforded the most opportunities for digital learning through the variety of coursework offered. Many students have opportunities to take advanced or college-level (dual enrollment) courses that utilize multimedia content, educational applications (apps), and interactive textbooks. Data (Pinnell & Biddle, 2022) show that 1:1 device programs in the U.S. increased from 61% in 2020 to 63% in 2021, and the trend is expected to continue. This initiative provides each student with a laptop or tablet. This enhances digital learning by allowing the student to access their digital learning resources both at school and in the community.

As with the lower levels in primary education, the administration side of secondary education also utilized multiple technology tools for recordkeeping, assessment, and other data reporting needs. Data analytics for secondary education is a key focus for the school administrators. Use of digital learning platforms assists them in generating valuable data on student performance and progress. Data-driven decision making is a key factor in state and federal reporting for this level of education. The teachers also use data from the learning platforms to assist with student support, remediation, or enhancement.

The impact of COVID-19 on digital learning

The worldwide pandemic, COVID-19, abruptly changed the levels of digital learning for all U.S. K-12 schools as it did for most educational systems globally. In the spring of 2020, the U.S. Department of Education (2022) reported that 77% of public schools had moved to online distance learning. This required educational systems to revise their approaches to learning and utilize more digital learning opportunities to engage their learners. This online approach continued through Fall 2020 and by Spring 2021, reportedly 52% of public-school students were again enrolled in in-person instruction (U.S. Department of Education, 2022). Technology support in the school year 2021-22 was reported at 96% nationally for providing digital devices to students who needed access to them, and 70% of public schools provided internet access at homes, while 49% provided access at locations other than homes for students who had no other means of internet access (U.S. Department of Education, 2022).

During the emergency teaching conditions of the COVID-19 pandemic, educational systems moved to emergency remote learning in attempts to continue presenting educational services for all learners. This move was facilitated for the most part by offering digital or virtual learning opportunities via online video systems or school-provided LMS systems. Virtual schooling, defined as instruction for which students and teachers are separated by time and/or location with interactions via technology more than doubled in application from 2013-14 to 2021-22 (200, 343 to 566,188), which was a 182.66% increase because of the pandemic. This figure includes all virtual schools including regular, special education, vocational, and alternative educational settings. By educational level, prekindergarten showed no change with 0% virtual, elementary (22,864 to 65,579), a 186.82% increase, middle school (lower secondary) (1,414 to 22,993), a 1,526% increase, and secondary and high schools (31,392 to 111,703), a 244.85% increase (National Center for Education Statistics, 2022).

Several key features of the emergency switch to full-time remote digital learning included access to digital devices and broadband, learning recovery and tutoring required for students upon returning to in-person instruction (Institute of Education Sciences, 2022). In the switch to emergency remote digital learning for K-12, only 61% of public-school educators felt they had the support and resources they needed to be effective (rated as somewhat or strongly agree). Digital learning real-time interactions such as live video or audio lessons for public school educators and students was ranked at 46%. A key factor was the digital divide, where access is not consistent throughout all parts of the U.S., with public schools undertaking steps to ensure connectivity via digital devices such as hotspots or other devices at 61%. Public schools also offered spaces where students could safely use digital learning devices during the pandemic. Sen and Tucker (2022) asserted that there is a "child digital infrastructure divide" (p. 2) whereby lower income families with children have internet access but it is based on cellular access not broadband, which is incumbent with widespread data-usage and data-speed limitations, making it a poor substitute for access. Access was inequitable as city and suburban schools had higher rates of access at 52% and 49% respectively compared to town and rural areas of 42% and 36% respectively. Towns and rural areas were able to compensate by providing higher access to free public internet spaces at 46-47% higher rates than city and suburban schools (Berger et al., 2022). U.S. public school systems also reported that they provided digital literacy training for students and families during this time at 72% for students and 25% for families, with approximately consistent rates throughout the U.S. regions (Northeast 68%; Midwest 75%; South 73%; and West 72%) (Institute of Education Sciences, 2022).

Learning recovery data showed students were on average a grade level behind after the closures and emergency digital learning during the pandemic in the 2021-23 school years. Considering digital divide issues with lack of connectivity and unfamiliarity with fully digital learning, one could surmise that digital learning was a contributor to this deficit. Engzell et al. (2021) posited that less time studying and home backgrounds were also contributing factors to learning loss.

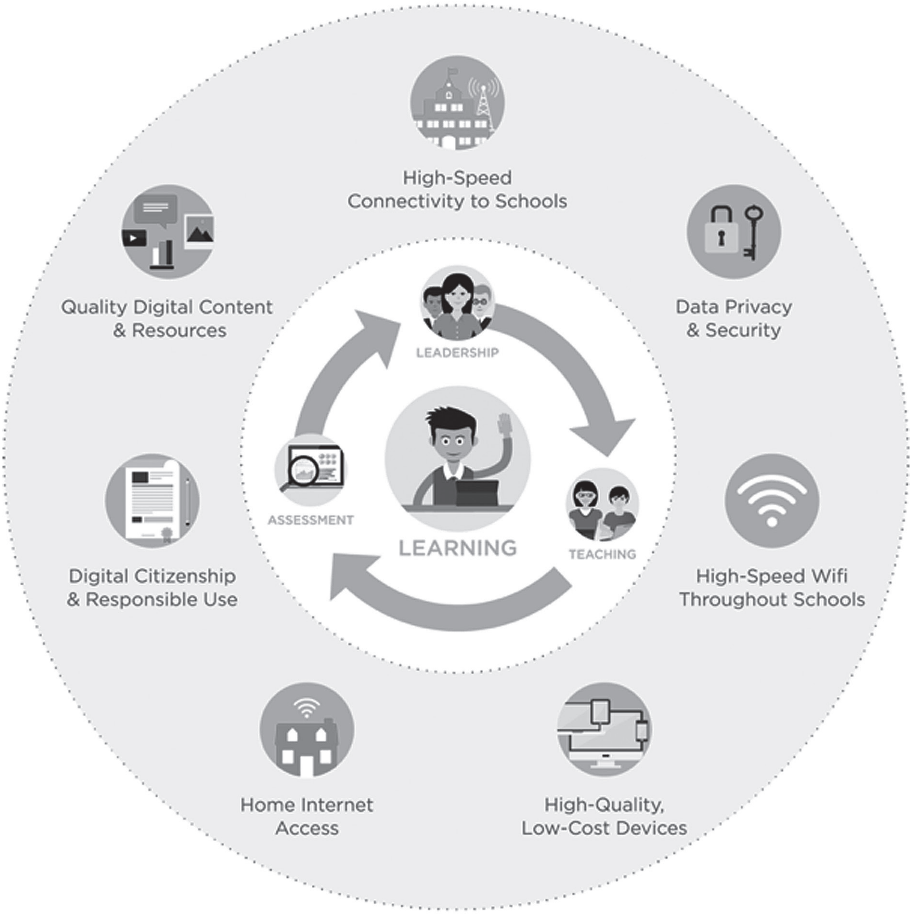
Tutoring was offered in public schools to assist with learning recovery, but again varied by locality and rigor (intensive high dosage, standard, or self-paced). Overall, 59% of public schools offered standard tutoring, 37% high dosage, and 22% self-paced. The mode of tutoring offered was predicated by funding (49%), lack of staff (40%), and time limitations (44%) (Institute of Education Sciences, 2022). Lack of materials was not a strong actor (6%), and digital learning opportunities are prime candidates to assist in tutoring, especially in self-paced or standard modalities. Digital tutoring would lessen other constraints listed previously such as funding, staff, and time.

Digital learning infrastructure

The Office of Educational Technology NETP website (n.d.a.) states essential components for successful infrastructure to support transformational learning include and address the following components:

- Ubiquitous connectivity. Persistent access to high-speed Internet in and out of school
- Powerful learning devices. Access to mobile devices that connect learners and educators to the vast resources of the Internet and facilitate communication and collaboration.
- High-quality digital learning content. Digital learning content and tools that can be used to design and deliver engaging and relevant learning experiences.
- Responsible Use Policies (RUPs). Guidelines to safeguard students and ensure that the infrastructure is used to support learning (para.1).

Figure 2 Infrastructure: To Support Everywhere, All the Time Learning



Note. Office of Educational Technology, National Educational Technology Plan, Section 5. https://tech.ed.gov/netp/infrastructure/

The Office of Educational Technology developed a vision for digital equity and transformation for all K-12 educators so they can thrive in digital learning environments, use technology for professional development, create effective digital learning coursework and experiences, and collaborate with their school leaders with technology approaches appropriate to the vision, culture, and infrastructure of their school (Office of Educational Technology, n.d.a.)

DL infrastructure in K-12 schools

Infrastructure in U.S. public schools was promoted through various federal acts and laws as well as local initiatives, but the equity in availability of digital learning assets still varied by state and localities, urban as compared to rural specifically. ConnectED (2017) was an initiative by President Obama to increase high speed internet for 99% of the nation's students' low-income households by 2018. This initiative would see a lack of progress as the pandemic began in 2020.

Digital learning infrastructure in K-12 schools is vital for all students to have equitable access to learning opportunities and to leverage high-quality learning resources. High quality resources include technology devices provided by the school system, consistent high speed internet connectivity, technology leadership and dependable budgeting practices, access to open educational resources, and protections for student data and privacy through the intentional use of responsible use policies (Office of Educational Technology, n.d.). Flexible infrastructure is a term used by some school systems to promote agility in spending technology funding by promoting openly licensed educational resources and open sharing of these resources with other systems.

School-provided technology devices, desktop computers, tablets, Chromebooks, or laptops, are key to a school's infrastructure. Slightly less than half of U.S. public schools reported they have a computer for every student (45%) and 37% reported having a computer for every student in some grades or classrooms (Gray & Lewis, 2021). One-third (34%) of schools reported that computers were assigned to individual students for use during the school day, and 15% of schools reported students were allowed to take computers home. According to Mouhanna (2019), at the school district level, schools not having a 1:1 program rated Bring Your Own Device programs (BYOD) at 65% for students. Internet connectivity was ranked as high for most schools (64%), yet there is still a disparity for the more remote, rural areas of the U.S. in providing connectivity (Gray & Lewis, 2021).

Digital learning leadership and technology support are key components of K-12 infrastructure. The U.S. Department of Education, Office of Educational Technology, published a nonbinding guide to digital leadership to assist in ensuring school leaders embrace digital learning and all it entails. The guide provides leaders with resources to help them “consider, plan, fund, implement, maintain, and adapt learning programs that meet the unique needs and requirements of the students and teachers that you serve” (Office of Educational Technology, n.d.b., p. 4). This guide promotes key constructs such as:

- Developing a shared vision and goals
- Prioritizing professional learning for teachers
- Assessing, building and maintaining your school’s infrastructure
- Personalizing learning for students, specifically competency-based learning and real-time assessments
- Collaborating with parents and families (Office of Educational Technology, n.d.b.)

Key statistics and practical examples

The National Center for Education Statistics (NCES)(2021) Fast Response Survey collected data from approximately 1,300 public schools in the 50 states and the District of Columbia (D.C.). This survey collects findings from schools as part of the National Educational Technology Plan (NETP) developed to provide a blueprint for using technology to improve learning. This survey reports findings about their technology use for teaching and learning during the 2019-2020 school year (pre-pandemic). The report is designed to present data on technology resources and how select school systems throughout the U.S. utilize these resources to ensure students are receiving a quality educational experience. The survey also queried teachers about challenges faced in using technology, training received for using technology, and staff support to assist in using technology. Principals and other building staff, called respondents in the survey, were also questioned on views of how student learning is affected by their use of educational technology. Computers in the resultant data tables refer only to desktop, laptop, and table computers including Chromebooks and iPads. Smartphones were not included as a computer device (Gray & Lewis, 2021). Overall, the survey found that "8 out of 10 schools rated the overall quality of computers. . .as good or very good" (p. 3). Nearly two-thirds of the schools stated their internet connections in their learning areas were reliable, although more than half reported slight issues when large numbers of students were online relative to speed and connectivity. Another notable finding was that teachers felt they did not have adequate time to become familiar with new technology and then use it to teach (43% moderate to 22% large challenge) (Gray & Lewis, 2021).

Findings at the elementary level are shown in the following tables. The numbers represent the percentages from combined responses of public elementary schools reporting throughout the U.S. in this survey.

Table 1 School Provides Computers for Students, Elementary Level, 2019-2020

Characteristic	Yes	Yes, in some levels	No
Computer for every student	33	45	22
Allowed to take computer home	~	6	93

Note. Reporting standard not met. The coefficient of variation for this estimate is 50% or greater.Information is excerpted from Table A-1 , https://nces.ed.gov/pubs2021/2021017.pdf

Table 2 Access To And Quality of Educational Technology, Elementary Level, 2019-2020

Characteristic	Poor or fair	Good	Very good
Overall quality of instructional computers	19	52	29
Overall quality of software used for instruction	17	53	30

Note. Information is excerpted from Table A-3, https://nces.ed.gov/pubs2021/2021017.pdf

Notable findings about the extent to which computers meet schools' instructional needs of elementary students were reported at 47% large extent, 40% moderate extent, and 13% not at all or small extent. Also reported was how easy it was to find enough computers to use with students, with the rankings of 49% for always easy, 42% usually easy, and 9% always or usually difficult (Gray & Lewis, 2021).

Table 3 shows the findings on the use of online tools for instruction at the elementary level.

Table 3 Online Tools for Instruction, Elementary Level, 2019-2020

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Interactive textbooks	20	35	31	14
Non-interactive ("click through") textbooks	31	39	25	5!
Supplemental Materials	5	38	41	16
Self-contained instructional materials	12	31	35	24
Interactive experiences	22	57	19	~

Table 3 (continued)

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Resources teachers locate themselves	~	17	48	34
Online materials teachers created	7	47	34	13

Note. Interpret data with caution; the coefficient of variation is at least 30% but less than 50%.
~ reporting standards not met. The coefficient of variation for this estimate is 50% or greater.
Information is excerpted from Table A-4, https://nces.ed.gov/pubs2021/2021017.pdf

Teachers at the elementary level reported use of technology for instructional activities normally done in the classroom at 4% not at all, 33% small extent, 46% moderate extent, and 17% not at all, 51% small extent, 34% moderate extent, and 7% large extent (Gray & Lewis, 2021).

Table 4 shows responses to professional development statements about educational technology for elementary teachers.

Table 4 Elementary Teacher Use of Educational Technology, School Year 2019-20

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Are provided with professional development on mechanics of how to use a computer or software	8	49	34	11
Are provided with professional development on how to use technology for instructing specific curriculum areas	6	42	42	10

Note. Information is excerpted from Table A-5, https://nces.ed.gov/pubs2021/2021017.pdf

Of note, elementary teachers' response data showed 59% somewhat agreed

(20% somewhat disagree) that they were sufficiently trained in the mechanics of technology, 47% somewhat agree (29% somewhat disagree) that they were sufficiently trained to integrate technology, yet 51% strongly agree that they were interested in integrating technology into their instruction. Teachers also ranked challenges – small to moderate - in staying up to date with technology (75% combined), identifying high quality technology resources (78% combined), and helping students learn basic computer skills (79% combined) (Gray & Lewis, 2021).

From an administrative viewpoint, school respondents stated challenges with staying up to date with computers and software for the school were overall not a challenge (28% no challenge, small challenge 37%), not a challenge for adequate numbers of computers nor a challenge with insufficient or inadequate software (38% no challenge, 36% small challenge) and internet speeds were not a challenge (51%) (Gray & Lewis, 2021).

Lower secondary education data are shared below. Lower secondary had more opportunities to engage with digital learning as previously mentioned due to increased standardized testing and accountability on the part of the learners and educators.

Table 5 School Provides Computers for Students, Lower Secondary Level, 2019-2020

Characteristic	Yes	Yes, in some levels	No
Computer for every student	63	20	16
Allowed to take computer home	31	67	61

Note. Information is excerpted from Table A-1 , https://nces.ed.gov/pubs2021/2021017.pdf

Table 6 Access to and Quality of Educational Technology, Lower Secondary Level, 2019-2020

Characteristic	Poor or fair	Good	Very good
Overall quality of instructional computers	14	53	33
Overall quality of software used for instruction	10	56	34

Note. Information is excerpted from Table A-3 , https://nces.ed.gov/pubs2021/2021017.pdf

Notable findings about the extent computers meet schools' instructional needs of lower secondary students were reported at 62% large extent, 33% moderate extent, and 4% not at all or small extent. Also, reported was how easy it was to find enough computers to use with students, with the rankings of 55% for always easy, 38% usually easy, and 7% always or usually difficult (Gray & Lewis, 2021).

Table 7 Online Tools for Instruction, Lower Secondary Level, 2019-2020

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Interactive textbooks	7	29	42	22
Non-interactive ("click through") textbooks	18	45	30	7
Supplemental Materials	~	21	51	26
Self-contained instructional materials	11	29	40	20
Interactive experiences	16	60	21	4!
Resources teachers locate themselves	~	10	45	45

Table 7 (continued)

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Online materials teachers created	3	39	44	14

Note. Rreporting standards not met. The coefficient of variation for this estimate is 50% or greater. Information is excerpted from Table A-4 , https://nces.ed.gov/pubs2021/2021017.pdf

Teachers at the lower secondary level reported use of technology for instructional activities normally done in classroom at ~ for not at all [~ reporting standards not met], 14% small extent, 49% moderate extent, and 26% large extent. They also ranked activities possible only through use of technologies at 3%! not at all, 39% small extent, 44% moderate extent, and 14% large extent (Gray & Lewis, 2021). Table 8 shows responses to professional development statements about educational technology for lower secondary teachers.

Table 8 Lower Secondary Teacher Use of Educational Technology, School Year 2019-20

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Are provided with professional development on mechanics of how to use a computer or software	4	42	37	16
Are provided with professional development on how to use technology for instructing specific curriculum areas	2	39	42	17

Note. Interpret data with caution; the coefficient of variation is at least 30% but less than 50%. Information is excerpted from Table A-5, https://nces.ed.gov/pubs2021/2021017.pdf

Of note, lower secondary teachers' response data showed 57% somewhat agree (21% strongly agree) that they are sufficiently trained in the mechanics of technology, 57% somewhat agree (21% somewhat disagree as well as 21% strongly agree) that they are sufficiently trained to integrate technology, yet 49% strongly agree they are interested in integrating technology into their instruction. Teachers also ranked challenges – small to moderate - in staying up to date with technology (78% combined), identifying high quality technology resources (82% combined), and helping students learn basic computer skills (72% combined) (Gray & Lewis, 2021).

From an administrative viewpoint, school respondents stated challenges with staying up to date with computers and software for the school were overall not a challenge (32% no challenge, small challenge 37%), not a challenge for adequate numbers of computers nor a challenge with insufficient or inadequate software (55% no challenge, 19% small challenge) and internet speeds were not a challenge (47%) (Gray & Lewis, 2021).

Upper secondary education presented the highest level of public K-12 integration as the learners have more opportunities to explore elective coursework such as technology-based learning, and have more rigorous standards for mandatory coursework attainment for matriculation requirements. This level also provides opportunities for students to explore college-level coursework that is accompanied by enhanced use of digital learning opportunities.

Table 9 School Provides Computers for Students, Upper Secondary Level, 2019-2020

Characteristic	Yes	Yes, in some levels	No
Computer for every student	63	27	10
Allowed to take computer home	39	12	49

Note. Information is excerpted from Table A-1 , https://nces.ed.gov/pubs2021/2021017.pdf

Table 10 Access to and Quality Of Educational Technology, Upper Secondary Level, 2019-2020

Characteristic	Poor or fair	Good	Very good
Overall quality of instructional computers	19	51	30
Overall quality of software used for instruction	19	49	32

Note. Information is excerpted from Table A-3, https://nces.ed.gov/pubs2021/2021017.pdf

Notable findings about the extent to which computers meet schools' instructional needs of upper secondary students were reported at 57% large extent, 36% moderate extent, and 48 not at all or small extent. Also reported was how easy it was to find enough computers to use with students, with the rankings of 55% for always easy, 39% usually easy, and 7% always or usually difficult (Gray & Lewis, 2021).

Table 11 Online Tools for Instruction, Upper Secondary Level, 2019-2020

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Interactive textbooks	9	37	43	12
Non-interactive ("click through") textbooks	14	50	30	6
Supplemental Materials	#	20	56	24
Self-contained instructional materials	12	40	33	14
Interactive experiences	21	57	18	5!
Resources teachers locate themselves	~	8	44	47
Online materials teachers created	~	27	43	29

Note. ounds to zero. Iinterpret data with caution; the coefficient of variation is at least 30% but less than 50%. ~ reporting standards not met. The coefficient of variation for this estimate is 50% or greater. Information is excerpted from Table A-4 https://nces.ed.gov/pubs2021/2021017.pdf

Teachers at the upper secondary level reported use of technology for instructional activities normally done in the classroom at 0% (rounds to zero) not at all, 17% small extent, 49% moderate extent, and 34% large extent. They also ranked activities possible only through use of technologies at 3% not at all, 44% small extent, 40% moderate extent, and 14% large extent (Gray & Lewis, 2021).

Table 12 Upper Secondary Teacher Use of Educational Technology, School Year 2019-20

Characteristic	Not at all	Small extent	Moderate extent	Large extent
Are provided with professional development on mechanics of how to use a computer or software	4!	42	37	16
Are provided with professional development on how to use technology for instructing specific curriculum areas	2!	39	42	17

Note. Interpret data with caution; the coefficient of variation is at least 30% but less than 50%. Information is excerpted from Table A-5, https://nces.ed.gov/pubs2021/2021017.pdf

Of note, upper secondary teachers' response data showed 58% somewhat agree (21% strongly agree) that they are sufficiently trained in the mechanics of technology, 53% somewhat agree (20% somewhat disagree) they are sufficiently trained to integrate technology, yet 46% strongly agree they are interested in integrating technology into their instruction. Teachers also ranked challenges – small to moderate - in staying up to date with technology (72% combined), identifying high quality technology resources (78% combined), and helping students learn basic computer skills (76% combined) (Gray & Lewis, 2021).

From an administrative viewpoint, school respondents stated that challenges with staying up to date with computers and software for the school were overall not a challenge (34% no challenge, small challenge 35%), not a challenge for adequate numbers of computers nor a challenge with insufficient or inadequate software (56% no challenge, 22% small challenge) and internet speeds were not a challenge (49%) (Gray & Lewis, 2021).

Features of digital learning

Features of digital learning nationally include blended or *tradigital* learning, learner centered education with emphasis on communication, collaboration, creativity and critical thinking and personalized learning (Seymour, 2019). These learner and educator centered types of learning are fundamental to effective digital learning with technology devices.

Feature 1: Blended or tradigital learning

Prior to the global pandemic, blended learning was becoming a strong presence in U.S. educational settings. Research showed that student engagement, achievement and overall perceptions of blended learning increased. Students developed skills outside the curricular ones such as self-pacing and self-directing for learning (Hesse, 2017). Blended learning in the U.S. combines the traditional face to face experience with an online component. In the U.S., blended learning is termed as hybrid, hyflex, targeted, multimodal, or flipped learning. Seymour (2017) utilized the phrase "tradigital learning" to emphasize a blending of best teaching practices from the traditional classroom combined with those of a digital learning environment. The Pickering Local School District in Ohio was an early adopter of tradigital blended learning for all students, with a hybrid model promoted by Seymour. Clarke County

School District, Georgia, has a student population with 34 native languages spoken and 12,000 students with the third highest poverty rate for a county of its size (Office of Educational Technology, n.d.f.). They focus on aggressive multimodal learning through innovative learning environments with digital platforms aligned to make all content accessible to all schools.

Feature 2: Digital curriculum and resources

Teachers use digital textbooks, e-books, interactive whiteboards, and educational apps to enhance the digital learning experience. The value of digital resources lies in the ability to customize the learning environment to meet the needs of the learner as well as to meet the needs of the educational system.

Bouchrika (2023) reported that gamification of content is most used to enhance overall interest in the lesson content. He further stated, "Online educational videos (67%) are the most used learning materials in K-12 classrooms, followed by educational software or apps (6%). Only 17% of K-12 classes used e-books" (para. 12). Baltimore County Public School District system developed a multi-year comprehensive plan to integrate curriculum, instruction, and assessment along with infrastructure, policy, budget, and communication to ensure an equitable, effective digital learning environment is available for all students (Office of Educational Technology, n.d.c.).

Feature 3: Learning analytics

U.S. public schools have embraced the need for data mining and analytics to understand how students learn, and how to adapt their curricula to personalize the instruction and learning environment. Use of data to make informed decisions in school systems is not a new concept, but with the increased use of learning management systems and other applications to analyze online student behavior, U.S. schools are better poised to customize their educational experiences to maximize the learning opportunities for all students through modeling, profiling, and trend analysis (Office of Educational Technology, 2012). Sitka School District, Alaska, needed to transform to digital learning, and to do this they focused on developing a Professional Learning Community (PLC) and curriculum integration specific to the needs of the Indigenous population for Arts, culture, and technology. They developed standards based on learner needs that ensured a respect for the place in which they lived and valued as a community (Office of Educational Technology, n.d.e.).

Feature 4: 1:1 device initiatives

Many U.S. public schools have implemented 1:1 device programs whereby each student is provided with a laptop, tablet, or other digital device. The students can access their digital learning materials, collaborate with other students online, chat or email with their teachers, and complete their assignments digitally. McAllen Independent School District in Texas is a large system with 33 campuses and approximately 30,000 students. The system supports 60,000 access points for 100,000 devices for students. Its goal was to provide each student and staff member with a tablet or mini tablet and digital folders for progress monitoring (Office of Educational Technology, n.d.).

Feature 5: Digital privacy

The U.S. Department of Education, Office of Educational Technology, provides many policies and guidelines for all school systems to use to ensure student and educator privacy while using online resources. Consistent with educational privacy acts such as Family Educational Rights and Privacy Act (FERPA), Children's Online Privacy Protection Acts (COPPA), children's Internet Protection Act (CIPA), and Protection of Pupil Rights Amendment (PPRA), the office provides a Privacy Technical Assistance Center to provide a framework for service agreements, questions related to privacy, confidentiality, and security practices for school systems. Compliance with the previously mentioned acts is mandatory to receive federal funding at a competitive rate for broadband and computer budgeting. U.S. school systems understand the need to protect students under the age of 13 while using the internet or digital learning tools along with ensuring their school systems and libraries monitor concerns regarding students' access to obscene or harmful content over the internet (Office of Educational Technology, n.d.). Three large U.S. universities have developed programs for use in public k-12 schools to instruct students about online privacy, its danger, benefits, and appropriate use (Srivastava, 2020).

Trends and Issues of Digital Learning

U.S. educators acknowledge that digital learning is fast growing and increasingly being adopted by school systems despite some challenges associated with this growth. The sections below detail trends and issues faced by school systems.

Trends in digital learning

Trend 1: Online learning

Digital learning in the guise of online learning is here to stay, but has undergone dramatic changes in delivery, focus, and instruction since the remote emergency learning necessitated by the pandemic. School systems are now offering permanent virtual learning options and blended or flipped classrooms for students. The increased acceptance and use of online learning has also promoted an increase in the ease of digital tools and platforms to facilitate online learning, along with increases in internet connectivity access. Mobile learning is a sidebar trend to online learning as the increased demand for learning platforms has brought into focus the need for learning anytime, anywhere so the platforms are programmed to be easily accessible on mobile devices.

Trend 2: Personalized learning

Personalized learning is at the forefront of digital learning trends as educators can customize instruction and administer adaptive assessments customized to each learner's specific needs, focusing on their strengths and weaknesses in the content area. Bloom (1984) reported that students who received personalized learning outperformed others by 98%. In the U.S., the key components that are required to achieve personalized learning are flexible content and tools to meet the needs of the learner, targeted instruction, data-driven instruction (discussed below), and most importantly, student reflection and ownership of the learning. Personalized learning is touted as a new standard for students to achieve digital learning, especially those who are considered digital natives with innate desires to use technology in their learning. Personalized learning does require intense preparation, scalability, consistent instruction, and the ability to mediate between grade level standards and competency-based learning (Frackiewicz, 2023).

Trend 3: Coding and computer science

Many school systems are offering secondary school students coding and computer science courses. Schools are integrating the coding and computer science curricula into other core subjects to help learners understand the vital connections of these digital skills and literacy to mainstream academic learning.

Trend 4: Gamification and game based learning

Gamification and Game-Based Learning are trending nationally in the U.S. with 66% of K-2 teachers using games weekly or more often, 79% of grade 3-5 teachers, 47% of grade 6-8 teachers, and 40% of grade 9-12 teachers, according to a survey hosted by University of Michigan School of Information (2013a, para. 10). This survey reported that teachers used games or gamification for formative assessments specifically of facts and knowledge (68%), concepts and big ideas (64%), and mastery of specific skills (59%) (2013b, para.5). Gamification integrates game elements, such as badges, points, and leaderboards, into the learning process to enhance student engagement and motivation. Game-based learning uses educational games as a central component of instruction to teach specific skills and concepts in an interactive and enjoyable manner. Research showed that well-designed games will help students engage in those topics they may struggle with or not have much interest in such as mathematics (Novotney, 2015).

Trend 5: Augmented reality, virtual reality, and artificial intelligence

Augmented Reality (AR), Virtual Reality (VR) and Artificial Intelligence (AI) are often seen as the same digital tools, but they do have distinct differences, yet all are used in today's digital learning environments in the U.S. AR and VR experiences allow users to immersively interact with objects and the environment. AR "combines…virtual and real object in a real environment through mobile devices" (Al-Azawi et al., 2019, p. 37). This real-world experience by using computer-generated information as an overlay and virtual reality provides experiences that mimic real or very believable experiences in a virtual way of concept immersion (i.e., virtual field trips used in schools). AR and VR technologies are being increasingly integrated into the classroom experience to provide a more equitable learning experience for all school systems.

Chen et al. (2020) defined AI as not only a field of study but also as a study area. Chen further asserts that in educational settings, AI supports "intelligent education, innovative virtual learning, and data analysis and prediction" (p. 75267). Intelligent education assists in personalized learning, another digital trend, and data feedback is a trend described in the following paragraph. Chassignol et al. (2018) posited that "AI applications are in wide use by educators and learners today, with some variations between K-12 and university settings" (p. 17).

Trend 6: Data driven decision making

Another major trend is the use of data driven decision making and instruction. Schools are heavily into developing analytics gleaned from their learning management systems or other analytical tools to assess areas of improvement, track student progress, and make decisions. These analytics are data-informed results about digital learning or other instructional tools to enhance instruction and learning. As stated previously, AI plays a part in this data-driven analysis, specifically in data mining, prediction systems, evaluation and grading of papers and exams, and online learning scenarios (Chen et al, 2020).

Issues in digital learning

Issue 1: The digital divide

U.S. school systems face one of the largest issues due to a phenomenon defined as the "digital use divide" (Office of Educational Technology, 2017, p. 7). A traditional definition of this term, digital divide, denoted students with access to internet and devices at school and home versus those who did not. The emergency remote learning promulgated by the pandemic caused a marked increase in the connectivity offered throughout the U.S., with nearly half of public schools stating that they provided internet connectivity for those students who did not have home access or school systems, while more than 56% reported providing access at other locations such as libraries or parking lots (Institute of Education Sciences, 2022). Having access does not always include a high-speed connection (broadband) and the need to share one device in a home with slow, dial up connections still existed in some geographical regions of the country. Despite these emergency efforts during the global pandemic, nearly 12 million school age learners remained disconnected from digital learning due to connectivity issues, infrastructure, and lackluster adoption of digital learning programs (Reardon, 2021).

A student's socio-economic status impacts how likely they are to have access to technology required for digital learning. In the U.S., 35% of households with school-age students with an annual income of less than $30,000 do not have access to or easy availability of high-speed connectivity. Compared with households with incomes $75,000 and above, only 6% do not have high speed connectivity (Anderson & Perrin, 2018).

Issue 2: Digital "use" divide (expanded from digital divide)

With the insertion of the word use in the term, it now denotes learners who use technology in "active, creative ways to support their learning" from "those who predominately use technology for passive content consumption" (Office of Educational Technology, p. 7). Considerations of this definition are *active* and *creative* ways rather than *passive* consumption. Olszewski and Crompton (2020) asserted that the effect of digital learning is not necessarily guided by quantity and quality of educational artifacts, but "what students and teachers do with the technology available" (p. 7). This issue of lack of connectivity or lack of engaged creative digital learning affects all the trends listed above as each is integrally dependent on connectivity.

Issue 3: Equity and inclusion concerns

Although digital learning provides flexibility and personalized learning for students, it can also intensify existing inequities due to disabilities, special needs, or language barriers. Learners with exceptionalities (disabilities or language barriers) and English language learners struggle with accessing digital artifacts and other online resources. Students with special learning needs require technologies to support their learning needs, which often has an extreme impact on the school's already limited technology budget.

Issue 4: Professional development

Lack of professional training along with resistance to change and budget limitations are other typical issues educators and school systems report as barriers to higher levels of digital learning and engagement. Due to rapid changes in technology and accompanying artifacts, many teachers had to adapt quickly without access to sufficient professional development. Many teachers also lack current technology skills which impedes their learning process to navigate the digital learning platforms. A lack of timely training for teachers has led to varying levels of digital learning proficiencies throughout the nation. Many school systems utilized in-house trainers for their professional development, and often these trainers were newer to or were not trained in utilizing digital learning platforms. Time for dedicated professional development is also a factor in providing quality, timely learning opportunities as teachers are paid for teaching hours with limited time built in for professional development opportunities.

Issue 5: School infrastructure

School infrastructure is a concern as funding is provided by local and state systems, along with varying levels of funding from the federal government, and infrastructure changes and upgrades are expensive. School buildings themselves are often outdated with no budgeting to upgrade the physical facility, much less to increase technology infrastructure needs. Most U.S. school systems do have adequate IT support to keep the technology they have on site working, which is a stress reliever to the educators using the devices. Again, funding for school facility infrastructure including building maintenance and for technology can vary from system to system, and most rely on local support to provide as much digital learning as feasible within their allotted budget.

Conclusion

Digital learning and transformation are foundations in the advancement of United States public K-12 educational systems, and have experienced tremendous growth since the global pandemic (COVID-19) in 2020, like other countries. This unprecedented growth has shown that digital learning is vital to student engagement, persistence in learning, and equity in educational access.

Most U.S. public schools operate at minimum at the digitalization level, apart from early childhood education which restricts access to technology based on input from the American Academy of Pediatrics and operates at the digitization level (Stage I). Higher levels of transformation occur in lower and upper secondary education through higher education and skilled training facilities as the learners are exposed to more opportunities for collaborative, student-based learning (digital transformation).

Digital learning in the U.S. is firmly situated in most classrooms, with schools offering access to technology to all students, either in individual classrooms or via a 1:1 program. U.S. schools are adopting more digital curricula items such as e-textbooks, interactive textbooks, multimedia content, and educational apps (applications). Using digital learning, the school systems can collect and analyze student data, thereby providing valuable insights for educators to track progress, identify areas of improvement, and personalize instruction. This data-driven decision digital instruction informs teaching strategies, student interventions, and required curriculum modifications to meet individual learner needs effectively.

As stated, COVID-19 brought about drastic, immediate changes in the modalities used to present education in the U.S. as well as globally. School systems adapted to offering learning via online methods instituted the use of Learning Management Systems in many systems, and reviewed how education was offered to those who were unable to be present in the classroom. This change in instruction instituted many new digital tools to assist learners, and many of those tools are still in use for learners as systems decided to continue offering internet access and online learning for learners. Schools are also utilizing the LMSs instituted during the pandemic as improved methods of connecting content with the learners.

Infrastructure in U.S. public schools varies by localities, urban or rural for example, but for the most part, school systems feel they have adequate facilities. However, more is needed to push their digital learning into the transformative stage for learner centric design thinking. A major factor in infrastructure is the digital divide, also called the digital use divide. This divide is based on the geographic constraints of many systems to access high speed connectivity for their learners. Another key component is increase in professional development for all involved in U.S. K-12 education. These professional development learning opportunities enhance digital literacy, instructional technology skills, and pedagogical approaches for incorporating digital learning effectively for all learners.

Like other highly digital competitive countries, the U.S. school system is exploring how to integrate Artificial Intelligence (AI). Considering the upsurge in the prevalence of AI, President Biden and the White House formally asked IT companies to commit to voluntary standards to manage the risks posed by AI for all citizens. This is very impactful for K-12 education as cybersecurity and public trust including harmful bias, discrimination, and privacy are all key components of public-school infrastructure (The White House, 2023). K-12 education is endorsing digital literacy as a keystone for future economic and workplace success. Personalized learning is a trend that many systems utilized with the advent of the LMS tools, videos, and other applications to promote remote learning. Issues are the concerns about AI mentioned as well as the digital divide that is still prevalent in the country. Professional development is a concern as it is difficult to maintain currency in training with the rapid changes in technology applications.

Overall, the United States K-12 educational system is positioned to advance its digital learning tools and achieve a stronger foothold in digital transformation for all learners throughout the country. The government has proactively addressed issues and provided funding to assist school systems in overcoming challenges so that all U.S. K-12 students have an equitable opportunity to experience a high-quality digital learning experience.

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An International Comparison of Trends and Issues of Digital Learning in High-Digital-Competitiveness Countries

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Abstract

This chapter aims to compare the contexts, features, trends, and issues of digital learning (DL) in K-12 education among 11 high-digital-competitiveness countries. Based on the country-specific reports in previous chapters, the following findings about DL are presented: (1) Most countries claim to be in the second stage of digital transformation (digitalization), while three countries claim to have reached the third stage of digital transformation. (2) The governments of these countries have launched policies promoting DL, incorporating long-term strategies that involve investments in DL facilities and resources. Countries that consistently implement policies across their education systems are more likely to progress in developing DL, while others encounter challenges in allocating funding and ensuring equitable access to DL. (3) DL implementation across K-12 schools varies in degree. Secondary education (ISCED 2 and 3) offers more opportunities for using digital tools to support learning than younger age groups. Some countries restrict the use of DL in pre-school education (ISCED 0). (4) The COVID-19 pandemic has yielded both positive and negative impacts on DL. Countries with long-standing DL policies have effectively adjusted to distance/online learning in response to the pandemic. (5) Significant funding has been allocated to DL, focusing on DL infrastructure, teaching, and learning resources. Due to the COVID-19 pandemic, there has been a notable increase in investments in DL across these countries. (6) Most countries have well-established school infrastructure to support DL. However, in some countries, variations in DL infrastructure exist among different school types, districts, and households. (7) Learning management systems (LMSs) providing diverse functions for digital learning and assessment are widely used. (8) Most countries emphasize teachers' professional development in digital teaching by providing support on online training courses, teacher communities, and hubs for digital teaching resources. (9) Some common DL features shared by these countries include significant and comprehensive government investments in DL, a focus on fostering students' and teachers' digital literacy, and the enhancement of personalized and adaptive learning using DL resources. (10) Several significant trends in these countries encompass the widespread use of AI in education, an emphasis on enhancing teachers' digital teaching skills, and the development of students' DL proficiency through courses on computational thinking, coding, and programming. (11) Common issues have been identified, including a lack of clear guidance or planning, insufficient funding for improving and maintaining DL facilities, disparities in students' access to DL devices both at school and at home, concerns for DL security, and more. These trends and issues could serve as a foundation for proposing future research and development directions that aim to enhance DL for sustainable development.

Keywords: digital learning, K-12 education, high-digital-competitiveness countries, comparative analysis

Introduction

This book aims to strengthen the mutual understanding and connection between Taiwan and other countries with high-digital-competitiveness in promoting digital learning (thereafter called DL) in K-12 schools, so as to facilitate the development of each country's DL promotion projects; and to provide opportunities for countries with high digital competitiveness to share their experience in promoting DL, so as to facilitate international reference and common prosperity. The high-digital-competitiveness countries here refer to the top 21 (or top one third) countries listed in the International Institute for Management Development (IMD) World Digital Competitiveness Ranking 2022 (IMD, 2022). Among these countries, 11 were selected and accepted our invitation to share their experience of promoting DL. They are Australia (AU), Estonia (EE), Finland (FI), Germany (DE), Hong Kong SAR (HK), Israel (IL), the Republic of Korea (KR), Sweden (SE), Taiwan (TW), the United Kingdom (UK)[1], and the United States of America (US). Each country's report is compiled in the preceding chapters, which provide a comprehensive overview of the promotion of DL in their country.

Based on each country's report, this chapter compares the findings across the 11 countries. Nine comparative components are raised and discussed respectively, namely schooling system, the stage of digital transformation, DL main policies/programs/research, DL implementation in schools, the impact of the COVID-19 pandemic on DL, DL infrastructure, DL features, trends and issues. The DL in this book refers to the learning that is facilitated by digital technologies and gives learners some control over time, place, path, and/or pace in an effective way, combining different elements such as blended or virtual learning using mobile technologies, e-learning, etc. (IGI Global, 2023).

1 Because the UK does not have a single UK-wide school system, its report is based on England, which accounts for over 85% of the UK population.

It requires a combination of digital technology, content, and instruction. The following three sections illustrate international comparisons of these components.

An International Comparison of the Schooling System and the Digital Transformation Stage in K-12 Schools

This section compares the DL background of the 11 countries in terms of two components: the structure of the schooling system and the digital transformation (DX) stage in K-12 schools. Table 1 shows a summary of the comparative components for each country. The similarities and differences among these countries are discussed below.

Component 1: Schooling system

The K-12 education system in the 11 countries could be divided into four stages: level 0 to level 3 in accordance with the International Standard Classification of Education (ISCED). The term for each stage varies across countries. For example, terms such as early childhood education, kindergarten, pre-elementary, or lower primary education are used to describe the ISCED 0 level for children under 5/6 years old. Many countries have compulsory primary (ISCED 1) and lower secondary education (ISCED 2), and some countries have extended compulsory education upward to the upper secondary level (such as AU, IL, FI) or downward to early childhood education for 5-year-old children (UK). In addition to general education, most countries offer vocational education or specialized curriculum programs at the upper secondary education level tailored to students' interests and future career aspirations. It is noted that some countries provide national curriculum guidelines, strategies, and standards to guide teachers and to support the implementation of digital education across the entire education system (such as AU, EE, FI, HK, TW). AU is an example of a national curriculum being used to ensure common curriculum frameworks and learning outcomes across all schools. In other countries, such as DE and the US, there is no national curriculum; rather, federal states and schools have their own curricula, following common aspects.

Component 2: Stage of digital transformation (DX) in K-12 schools

DX refers to the process in which organizations utilize digital technologies to adapt to environmental changes (Vial, 2019). According to Luo and Wee's (2021) definition, DX is a journey of the following three stages. Stage I. Digitization: converting non-digital records and information into digital format. Schools usually use peripheral digital technologies such as digital desks and invest in isolated experiments like loyalty programs to prepare for the new activities, with only a few administrators aware of the school's future strategy. Stage II. Digitalization: converting processes or interactions into digital equivalents. Schools grasp the potential of technology and reorganize educational activities with digital tools, requiring additional investment in personnel training for effective use. Examples include e-learning and teleconferencing. Stage III. Digital Transformation: an innovative and disruptive education change, where strategic decisions are made with the aid of digital technologies. Schools can leverage student-centric design thinking to dig out their insights and enhance internal and external engagement. They prioritize innovative education approaches to build strategic competitive advantage for sustainable growth.

The country report authors were asked to indicate which stage most (i.e., more than half) of their K-12 schools are at now. Based on the self-assessment reports for K-12 schools in the 11 countries, three of them (HK, SE, TW) claim to have reached Stage III. These countries show a comprehensive DL transformation of whole educational networking from government policies to teaching practices. For example, digital learning in HK is a comprehensive integration of digital technology to transform education, with government policies, curriculum documents, and innovative projects all emphasizing a dedication to transformative and innovative education in K-12 schools. Besides, six countries (AU, EE, FI, IL, KR, UK) have identified themselves as being at Stage II, four of which (AU, FI, UK, KR) are moving towards the next stage. It is notable that DX progress in certain countries varies significantly among schools and regions. IL is an example, where gaps between different socioeconomic statuses and opposite policies about DL act as barriers to entry into the third stage. Challenges also arise from limitations in teachers' capacity and willingness to integrate digital tools into their teaching methods (such as EE, IL). In the case of DE and the US, primary education has reached Stage I, while lower and upper secondary education has, on average, advanced to Stage II. Similarly, a digital gap persists nationwide in both countries, particularly in rural and remote areas, where access to DL resources is limited. Overall, many countries have made significant efforts to accelerate the DX process in response to the disruptions caused by the COVID-19 pandemic, with the aim of providing innovative digital learning environments. Figure 1 displays the DX progress of the 11 countries.

Figure 1 The Digital Transformation Progress in K-12 Schools across the 11 Countries

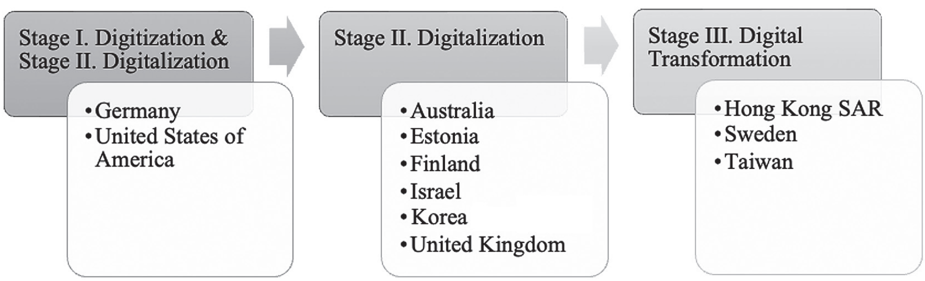

Table 1 Summary of Schooling System and Stage of Digital Transformation in K-12 Education across 11 Countries

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Schooling System	1. Four stages of K-12 education system: early childhood education (0-5/6 y/o), primary school (5/6-11/12 y/o), junior high school (11/12-15/16 y/o), & senior high school (15/16-17/18 y/o). 2. All students must complete year 10 & engage full-time in education or training until 17 y/o. 3. A robust regulatory framework and transparent accountability mechanisms: national curriculum published in 2012 ensures common curriculum frameworks and learning outcomes across all schools. 4. High level of privatization: 30% of students enrolled in private schools.	1. K-12 education system starts with optional kindergarten (1-6 y/o), then 9 years of compulsory basic school divided into 3 levels, each level lasts 3 years (7-16 y/o). 2. Often only constructive feedback without numerical grade is given to level 1 (primary school) students. 3. After graduation from basic school (15-16 y/o), students tend to continue studies in either secondary school or vocational school. After that, they can continue studies in higher education. 4. Educational practices are guided by the national curriculum, teacher professional standards, and national strategies, e.g., Estonian Education Strategy 2021–2035.	1. The school system consists of early childhood education and care (below 6 y/o, non-compulsory), followed by compulsory education including preprimary (6 y/o old), basic (7-15 y/o), and general or vocational upper secondary education (16-18 y/o). 2. Upper secondary education leads to the matriculation examination. Vocational education leads to vocational qualifications. 3. Students from both general and vocational upper secondary can continue studying in higher education.	1. K-12 education system covers elementary education (below 6/7 y/o), primary education (6/7 - 9/10 y/o), lower secondary education (9/10 -15/16 y/o), upper secondary education (15/16 - 17/18 y/o). 2. No standardized curricula. 16 federal states and schools have their own curricula, following common aspects. Primary and lower secondary education in all states are obligatory (at least 9 years). 3. Different educational pathways in the upper secondary level: general or vocational education schools. 4. The majority of schools are public; only 14% of general education schools were private in 2019.	1. Four levels of K-12 education: kindergarten (3-5 y/o), compulsory primary (6-11 y/o) and junior secondary education (12-14 y/o), and senior secondary education (15-17 y/o). 2. All kindergartens are private; 97% join the Government's "Kindergarten Education Scheme," offering free half-day services. 3. Primary/ secondary education have 4 types of schools: government schools, aided schools, and Caput schools are fully funded by the Government and run by religious, charitable, or clan organizations; the Direct Subsidy Scheme schools, are private. 4. The Government practically provides 15 years of free education from primary to senior secondary education.	1. Four stages: pre-elementary (3-5 y/o), elementary (6-12 y/o), junior high school (13-15 y/o), and high school (16-18 y/o). All are compulsory, except pre-elementary education. 2. Education system is relatively centralized, but geographically divided into 8 educational districts, responsible for implementing the MOE's policy and overseeing regions' learning activities. 3. Three unique components: Arab education, religious education, and ultra-Orthodox education, reflecting the diverse cultural and religious landscape. 4. The achievement gap between different socioeconomic & ethnic groups is the most pressing challenge.	1. K-12 schooling system entails early childhood education (3-6 y/o), elementary school (7-12 y/o), middle school (13-15 y/o), and high school (16-18 y/o). Elementary and middle education is compulsory. 2. Elementary education includes elementary/ miscellaneous/ special schools. Secondary education includes middle/ open middle/ civic high/ miscellaneous schools at ISCED 2 and high/open high/ trade high/ miscellaneous schools at ISCED 3.	1. K-12 education system is divided into four levels: voluntary preschool (1-6 y/o), compulsory elementary (7-12 y/o) and lower secondary education (13-15 y/o), & voluntary upper secondary education (16-18 y/o). 2. In upper secondary education, students can choose 1 of 18 national programs with a specialized curriculum based on their interests and future career aspirations. 3. Children with learning disabilities attend mandatory special school from the ages of 7 to 16, then choose optional special national, individual, or special-format programs for upper secondary education. 4. The school system is governed by the state and publicly financed and exempt from fees.	1. The school system commences with early childhood education (below 6 y/o), primary education (6-12 y/o), lower secondary education (12-15 y/o), and upper secondary education (15-18 y/o). Primary and lower secondary education are compulsory. 2. Primary and lower secondary schools follow the "Grade 1-9 Curriculum Guideline" (2001), effectively integrating the curriculum and teaching across both stages. 3. Upper secondary schools based on the "12-Year Basic Education" policy in 2014 are classified into 4 types: general, vocational, comprehensive, and specialized senior high schools.	1. No single UK-wide school system, with Scotland different from the other three home nations. 2. School sector in England is divided into pre-school (0-5 y/o), primary schools (5-11 y/o), secondary schools (12-16 or 12-18 y/o) and sixth form colleges (16-18 y/o). 3. Schools are either state schools (municipality-based schools, Academies and Free Schools) or private schools. 4. England education follows the national curriculum, and students usually take exams to gain GCSE(s). 5. To enter higher education, students study for 2 more years (after GCSEs) to gain A or T levels. Equivalent qualifications can be attained via vocational routes (college/ apprenticeship providers).	1. K-12 system encompasses elementary education, divided into lower (3-5 y/o) and upper primary schools (6-9/11 y/o) and secondary education with lower level-middle schools (10-13 y/o) or junior high school (12-15 y/o) and upper level-high schools (14-17 y/o) or senior high schools (16-18 y/o). 2. A wide variety of regulations, laws, court decisions, and local policies to define educational systems in each state, following the policy and oversight of the U.S. Department of Education. 3. Numerous adult & continuing education opportunities (workforce training/special education program) throughout many educational levels.

Table 1 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Stage of Digital Transformation (DX) in K-12	1. **Stage II.** Digitalization has been achieved at all levels: technologies play an integral role in the administration, communication, and financial functions in each school. 2. **Stage III.** Digital transformation: governing bodies at each level routinely employ digital technologies to collect, analyze, and report institutional data, aiding in decision-making.	**Stage II.** Digitalization: Estonia has reached the stage of digitalization, but not yet the stage of digital transformation.	1. **Stage II.** Digitalization: FI is in an advanced stage of digitization, digitalization, and digital transformation. 2. FI has been progressive in digitization and digitalization, but the extent of digital transformation (**Stage III.**) in education varies across schools and regions.	1. **Stage I.** digitization for elementary and primary education levels; and **Stage II.** digitalization for lower and upper secondary education on average, with upper secondary level schools appearing to be slightly more advanced. 2. There are many variations of digitalization in the different states and even in different institutions in the same district.	**Stage III.** Digital Transformation: HK's DL is characterized by a comprehensive integration of digital technologies to transform education. The government's policies, curriculum documents, and innovative projects all demonstrate a commitment to innovative and disruptive education transformation in K-12 schools.	**Stage II.** Digitalization: The MOE has invested a lot of resources in using digital technology for educational transformation, but some existing policies work in the opposite direction, making such transformation difficult to achieve. Most teachers still use technology only to augment educational practices.	1. **Stage II.** Digitalization: the majority of K-12 schools reorganize and optimize educational activities by using various digital tools for teaching and learning. 2. KR has taken significant strides towards digital transformation, embracing innovative changes in education through digital technology	**Stage III.** Digital Transformation: Sweden has reached a point where digital access is adequate at all levels of education, reaching Stage III of the DX journey.	**Stage III.** Digital Transformation: all schools from grades 1 to 12 are situated in the DX phase. The progress is built on projects: Grades 1-12 School Action Learning Project (2012-2018), Special Act for Forward-Looking Infrastructure 1.0 (2017-2020), Technology-Assisted Self-Regulated Learning Project for Primary and Secondary School (2019), Promotion of Grades 1-12 School Digital Learning Enhancement Plan (2021~).	**Stage II.** Digitalization 1. Most UK schools are at the end of Stage II, noting that this stage is perpetual as systems are continually updated. 2. Digital K-12 advances are fragmentary in terms of transformation beyond Stage II. However, there are many examples of good practice.	1. **Stage I** (digitization) for lower and upper primary education, under transforming to stage II. 2. **Stage II** (digitalization) for lower and upper secondary education. 3. There is still a digital divide across the country, with many areas, especially rural, remote areas, having minimal access to DL resources.

An International Comparison of the Current Status of DL in K-12 Schools

This section presents a comparison of the current status of digital learning in K-12 schools for the 11 countries. The content includes five comparative components, namely: main DL policies, programs and research, DL implementation in K-12 schools, the impact of COVID-19 on DL, DL infrastructure, and features of DL. The relationship among these factors portrays the networking and ecosystem of digital learning in each country. Table 2 summarizes the information of the aforementioned components across countries.

Component 3: Main DL policies, programs and research

This section discusses the nationwide and/or statewide DL policies, projects, programs, strategies, and research and development (R&D) findings in the 11 countries. All of these countries have policies aimed at promoting DL in K-12 in various aspects, such as investing in digital infrastructure, enhancing teaching and learning activities with information and communication technologies (ICT), and developing digital literacy among students, teachers, and other stakeholders. These policies can be issued directly by the national government or the Ministry of Education (MOE), with effects spanning states or counties (e.g., EE, FI, HK, KR, SE, TW), or formulated by local governments following national guidelines or strategies (e.g., AU, DE, US). For example, in DE, although the national and state governments have limited influence over the implementation of the education system, local authorities directly influence the funding of digital infrastructure. Schools are also free to establish their own curricula and manage their own IT equipment for educational purposes, leading to a diverse and varied digital educational landscape.

In some countries, DL has a long history, with the government and MOE implementing long-term strategies to promote the use of ICT in teaching and learning (e.g., AU, FI, HK, IL, KR, TW, UK). For example, FI has been implementing DL since 1980, with three strategies, including developing digital infrastructure, evaluating the benefits of using technology for teaching and learning (2005-2010), and recognizing diverse needs and uses of digital technologies for learning (2011-2018). In TW, the government has implemented two types of policies. The first type focuses on establishing ICT infrastructure across campuses through six policies from 1998 to 2025, such as the development of computer classroom environments (1998-1999) and the provision of mobile devices and internet connections (2022-2025). The second type aims to enrich digital learning content, comprising five key policies from 2001 to 2025, such as the integration of technology into teaching and learning (2001-2007) and the enhancement of materials and educational big data (2022-2025). In addition to supporting DL, digital competence and literacy are mentioned as core outcomes in national curricula and strategies (e.g., AU, FI, DE, HK, KR, SE, US). Generally, DL policies in different countries tend to start with the construction of digital infrastructure, then progress to the development of digital content, the empowerment of teachers' pedagogy, and the enhancement of students' digital learning literacy.

With regard to DL research and development (R&D), considerable effort is being invested in studying practical tools, technologies, and pedagogical approaches. In addition to research activities in higher education, various companies and centers are dedicated to DL research and development. For instance, the Center for Education Technology (CET) in IL is a notable community interest company that focuses on researching and providing DL educational technology, content and resources, and teachers' training. In the US, the government funds several national centers to conduct research in the field of DL. “Precision Education: the Virtual Learning Lab” is an example that emphasizes personalizing and enhancing virtual learning.

Component 4: DL implementation in K-12 schools

Alongside clear policies and guidelines, several countries have embraced the widespread implementation of DL across all educational levels, school types, and domains in K-12 education (e.g., HK, KR, SE, TW, UK-England). For instance, TW has developed DL programs for various subjects and core competencies at all levels in primary and secondary education, as part of the "Promotion of Grades 1-12 School DL Enhancement Plan - 2021." It is notable that the frequency and types of DL applications vary across educational levels, with more prevalent and advanced use of digital technology in the later stages of education (such as AU, DE, HK, IL, US). For example, DE reported sporadic use of digital media in kindergartens and primary schools due to budget constraints and a shortage of technical staff. In IL, preschool teachers and parents consider the use of digital tools unnecessary for preschool children, leading to limited digital applications for this age group and restrictions on children's internet exposure set by the MOE. As for the upper secondary schools, a wider range of digital device options and advanced DL content are provided. Taking SE as an example, preschool children start using tablets to learn basic programming, math, and reading skills, while upper secondary school students utilize virtual reality and augmented reality technologies to explore complex concepts.

The implementation of DL also relies on the degree of teacher autonomy in teaching. Teachers in countries such as EE, DE, FI, and IL have the autonomy to decide on the use of DL in teaching, resulting in varying levels of DL implementations based on their perceptions and readiness to apply DL. The DigiEfekt project in EE revealed several factors that teachers consider, such as the availability of digital content, ease of monitoring the learning process and providing feedback, and student access to learning tasks or content. Overall, the 11 countries tend to allocate digital resources to the development of subjects such as mathematics, science, and languages. Some countries, such as AU, FI, KR, SE, and the US place emphasis on developing students' digital skills through coding and robotics programs, as digital literacy is regarded as an essential outcome of the national curriculum. Various DL applications are observed in K-12 education across countries, including videos, e-books, online courses, Learning Management Systems (LMS), gamified testing systems, VR, AR, multimedia, digital assessment tools, etc. In recent years, the implication of AI has been noted in supporting adaptive learning by integrating it into LMS and textbooks in KR and TW.

Component 5: The impact of COVID-19 on DL

Although the Covid-19 pandemic led to school lockdowns and disrupted traditional face-to-face education, it has accelerated the transformation of digital learning in schools. As mentioned earlier, several countries (such as EE, FI, HK, IL, KR, TW, UK) had formulated long-term national strategies or policies to promote the digitization of education before the outbreak of COVID-19. Consequently, they were able to swiftly implement large-scale online educational systems during school lockdowns. For example, the EE report indicates that the majority of teachers and students were prepared to handle the emergencies because they had experimented with online learning during previous e-learning periods when students self-studied at home using digital material provided by their teachers. In FL, with previous support from the national promotion of DL, large-scale online education was able to be urgently implemented during the pandemic.

In addition to the efforts made before the pandemic, most countries allocated funding and support to enhance digital infrastructure, learning content and resources during the school lockdowns. For instance, the AU government and schools subsidized home internet and device costs for disadvantaged students, and improved internet connectivity in remote areas. In the US, technology support for public schools was implemented to provide students with digital devices and internet at home or other locations. Similarly, the MOE in KR distributed smart devices, introduced public LMS platforms, and facilitated the establishment of wireless networks in all schools. Moreover, many countries (such as AU, FI, DE, IL, KR, SE) attach great importance to teachers' professional development by providing DL training courses, online communities, sharing forums, and resources to help teachers successfully transition to online teaching. Based on these efforts, a variety of online or hybrid teaching approaches were implemented to meet student needs. For example, in the UK, primary school students use information from websites for asynchronous homework, while secondary school students participate in synchronous learning courses through platforms such as Zoom, Google Classroom, or Microsoft Teams.

There is no doubt that the pandemic has propelled a positive shift toward DL in schools, but it has also led to some adverse outcomes or challenges, such as inequality in DL facilities or access (AU, FI, US), students' mental health and well-being (AU, EE, UK), and disparities in digital literacy levels among teachers or students (FI and UK). Concerns also arise regarding the sustainability of DL after the pandemic, as seen in Israel, where the percentage of schools using digital cloud infrastructure and DL content dropped from 80-90% during the pandemic to 40-50% post-pandemic.

Component 6: Digital learning infrastructure

Six critical elements contribute to the success of DL infrastructure, including leadership and budget, course design and delivery, student success in DL, assessment and data analysis, professional development for teachers and staff, and technological infrastructure (such as bandwidth) (Fox et al., 2021). Based on this, a comparison of DL infrastructure in K-12 schools across the 11 countries is presented below.

For leadership and financial resources, most countries allocated substantial funding to DL infrastructure, particularly during the COVID-19 period. For instance, the ICT budget in KR education increased from 807,725 million KRW in 2019 to 1,557,670 million KRW in 2022. Such funding originated from various sources, as seen in EE, where the Estonian state budget and European structural funds serve as two major funding channels. The funding enables schools to establish digital DL infrastructure, enhance Wi-Fi bandwidth, develop DL curriculum and teaching resources, and provide professional development for school leaders and teachers. This reinforces the effectiveness of all nodes in the DL network, supporting students' digital learning. The funding allocations differ depending on the state, locality, and school type (DE and US). Taking DE as an example, there is considerable variance in the DL infrastructure across schools, which is closely linked to the financial capabilities of the respective state and the responsible authorities. In addition, schools and leaders in some countries (such as DE, FI, US) have a high degree of autonomy in leading a school's digital transformation and budgeting for developing DL infrastructure and updating devices. Therefore, significant gaps in the basic digital infrastructure of schools are evident in countries like DE and the US, particularly in primary and lower secondary schools, where essential components such as wireless LAN, learning management systems, and networked collaborative tools are not readily available. The equity in the availability of DL assets is a concern across the 11 countries.

Regarding course design and delivery, learning management systems (LMS) are commonly employed to facilitate DL across various countries, including AU, EE, DE, IL, KR, TW. In EE, LMSs are primarily utilized for communication among the school leadership team, students and parents, and provide learning activities and tasks with interactive DL materials. In contrast, DE and KR have developed numerous DL platforms with AI support, aiming for adaptive and personalized learning. Some national assessment online platforms provide teaching material and assessment tools to analyze learning data, such as "The Student Evaluation Support Portal" in KR, "Technology-based Assessment" in DE, and the “Taiwan Adaptive Learning Platform” in TW. In IL, virtual spaces like Springboard and Bagroup were created to provide learners with success-oriented experiences, thereby boosting their learning motivation. Evidence of student achievement in DL was scarcely mentioned in the country reports, with references largely limited to PISA data, national testing data, and the prevalence of students using digital devices. Again, teacher autonomy plays a significant role in deciding learning delivery and teaching methods. For example, in AU, schools and educators are free to shape the design and the delivery of digital content, adhering to the guidelines set by the Australian Curriculum, Assessment and Reporting Authority.

Professional development programs or courses for educators and staff in DL are provided across the 11 countries, with training courses for teachers being the most common approach (AU, EE, HK, IL, KR, UK). These courses are often conducted in remote or online learning environments, providing a wide range of options. In the UK, teachers have access to numerous online courses available on platforms such as FutureLearn and EdTech. Some platforms, like eSchool Bag in EE, a national hub in Sweden, and the KERIS hub in KR, have been established to share digital teaching materials and to support teachers in designing and conducting their teaching. In Taiwan, the "DL guidance team" (comprising central and local teams) was launched in 2019 to assist teachers and schools in adopting DL. In IL, 90% of schools have a techno-pedagogical or computation coordinator. Sweden has introduced a new master's program focusing on educational technology to train future DL staff. All of these efforts aim to help teachers and staff successfully transfer to the digital teaching environment.

In terms of technological infrastructure, many countries (FI, HK, IL, KR, SE, TW, UK) have well-established school infrastructure to support DL, including digital devices, high-bandwidth internet connections, digital classrooms and so on. Following government policies, substantial funding has been allocated to bolster technological infrastructure, creating a strong foundation for the implementation of DL. Furthermore, many countries have invested in specialized digital tools, such as 3D printers and programmable robots. For instance, in FI, three out of four schools have robots, and every second school is equipped with a 3D printer. Regarding home access, HK reported that 90% of students had access to computers and the internet at home in 2022. In contrast, DE and the US have observed disparities in technological infrastructure among types of schools and regions.

Component 7: Features of digital learning

The author(s) of each country in this book have highlighted three to five DL features in their own country report (see Table 2). These features were derived from comparisons with K-12 schools in other equivalent countries or from comparisons of K-12 schools and colleges within their country. Based on these highlights, we extracted the key concepts in each country report and then generated a word cloud, presented as Figure 2. In the word cloud, the size and boldness of each term correspond to its frequency and importance in relation to the DL features across the 11 countries.

Figure 2 A Word Cloud of the DL Features in the 11 Countries

Based on the visual representation above, the most prominent term is "investment." This signifies that most countries have dedicated substantial money and energy to improve their digital infrastructure conditions, such as computers, internet, digital learning content, materials, LMS, teacher professional development programs, and more. Several countries, such as DE, KR, TW, and US, have highlighted their DL features in this regard. Taking KR as an example, the national-level Master Plans for ICT since 1996 have facilitated continuous progress in DL. Additionally, there are strong emphases on training teachers' digital competencies, developing learner-centered platforms, and creating digital textbooks. Such substantial investment in advanced infrastructure plays a vital role in the success of DL in KR.

The next highlighted feature is personalized and adaptive learning, especially observed in country reports from KR, TW, US, and IL. In KR, various learner-centered platforms provide personalized feedback, generate test papers, and offer learning diagnostics tailored directly to students' needs. Another example involves the collaboration to integrate the Taiwan Adaptive Learning Platform (TALP) and the Project for Implementation of Remedial Instruction-Technology-Based Testing System in Taiwan. This collaboration aids in planning personalized learning paths for low-achievement students during remedial instruction. Moreover, in IL, TW and the US, big data from learning analytics and school data management are employed to enhance students' learning processes.

The third feature is to cultivate the digital competence of both students and teachers to adapt to the digital learning context (AU, EE, HK, KR). Nurturing students' higher-order thinking is particularly emphasized in HK, EE, and AU. For example, in AU, students are required to study Technology and Digital Literacy from grade 8, and a mandatory coding program is introduced from grade 3 to enhance their computational thinking, system thinking and design thinking skills. Moreover, some countries (HK, IL) have highlighted the strong connection between the government, schools, and families as a crucial feature for promoting effective digital learning.

The fourth shared feature is the concern about inequity in DL within K-12 education across several countries (FI, SE, UK, US). Differences in socioeconomic levels and regions notably impact students' DL experiences and digital skill levels. For instance, in SE, students from low-income families may lack access to technology and resources, leading to a digital literacy gap between student groups. Many countries are actively seeking solutions to address the equity issue. For instance, in TW, government funding prioritizes schools in remote areas, providing them with a wealth of free DL resources. Meanwhile, in the US, many public schools have implemented '1:1 device' programs aiming to provide each student and staff member with a tablet, laptop, or other digital devices.

Finally, several unique features are highlighted in different countries, such as teacher shortages (EE), homeschooling (UK), blended learning (US), digital privacy (US), and students' mental health and safety (AU). The differential efforts or concerns emphasized in these countries shed light on their experiences in promoting DL within their educational context and the status of DL implementation, serving as a valuable reference for the international community.

Table 2 A Summary of the Status of Digital Learning (DL) in K-12 across 11 Countries

Component	Countries										
	Australia (AU)	**Estonia (EE)**	**Finland (FI)**	**Germany (DE)**	**Hong Kong SAR (HK)**	**Israel (IL)**	**Korea (KR)**	**Sweden (SE)**	**Taiwan (TW)**	**United Kingdom (UK)**	**United States of America (US)**
Digital Learning Policies/Programs/Research	1. The national curriculum emphasizes all levels of students to be active participants in DL. 2. Teachers actively use technology to enrich content and provide students with access to learning resources (78% of teachers allow students to use technology devices). 3. Preschool emphasizes natural, hands-on, play-based learning experiences with technology support such as interactive digital storybooks, educational apps. 4. Technology education becomes more specialized as students transition from primary to secondary school, reflecting the diverse subjects and the depth of content explored. 5. Coding program is provided for students from primary schools (Scratch Jnr, Bee-Bots, Code.org) to secondary schools (Python, Ruby, Java or C++, etc.). Coding is a requirement of the curriculum from Year 3, and these tools are routinely used.	1. A policy related to the adoption of digital learning goals has been issued by the Estonian Ministry of Education and Research. 2. MA in Educational Technology, a program that supports training human resource specialists and entrepreneurs in the field of educational technology was launched in 2017. 3. DigiEfekt project, a large-scale study conducted in the 2021-2022 academic year, examined the effectiveness of digital learning on students in the 3rd, 6th, and 9th grades.	1. The first initiatives in using digital technology in education were implemented in the 1980s. 2. Three phases in promoting DL: -The 1st phase focused on digital infrastructure (1998-2004). -The 2nd phase focused on evaluating the benefits of using technology for teaching and learning (2005-2010) -The 3rd phase recognized diverse needs and uses of digital technologies for learning (2011-2018) 3. Digital competence is not directly mentioned in Finnish policy strategies, but ICT competencies are referred to in the Finnish national K–12 curriculum in 2016. 4. The New Literacy Skills program emphasizes the learner's right to develop digital competence and literacy.	1. While national and state governments have limited influence on education system implementation, local authorities directly impact digital infrastructure funding. 2. Schools are free to set up curricula and IT equipment for administration and education, leading to a heterogeneous landscape. 3. Quality Offensive Teacher Education in 2013 fostered teacher education, with an additional initiative emerging in 2018 to promote the digitalization of teacher education. 4. Since 2014, the KMK and national government have issued strategies to enhance DL and digital competencies in curriculum, e.g., "Digital Agenda 2014-2017," "Education offensive for the digital knowledge society," etc. 5. "Digital Pact" (2019-2024) supports DL and initiates many projects at the national level, bridging across states, contributing to digital infrastructure development and enhancing teacher qualifications.	1. The Government had a commitment to promote information technology in education with 4 strategies from 1998 to 2016: -Information Technology for Learning in a New Era, 1998/99 to 2002/03, focused on infrastructure building. -Empowering Learning and Teaching with Information Technology from 2004 to 2007, focused on human capacity development for DL. -Information Technology in Education: Right Technology at the Right Time for the Right Task 2004 to 2008, focused on the successful integration of IT into education. -Information Technology in Education - Consultation Document 2015/2016, focused on unleashing students' power of learning to learn. 2. The Government reiterates digital literacy in various documents, showing that HK attaches great importance to DL in primary and secondary education.	1. The MOE launched the National Digitization of Education program in 2010, aiming to improve digital infrastructure in schools in the first 10 years, then changed focus to managerial and pedagogic infrastructure over the last 5 years. 2. Some educational technology startups invested in developing DL tools and resources. 3. Center for Education Technology is the largest community interest company in educational technology, developing online learning environments, platforms, teacher training, resources, and guidelines to integrate technology into classrooms. 4. The MOE provides laptops to students who cannot afford them, and encourages learning in the "Bring Your Own Device" program that supports school digital lessons.	1. The MOE formulates national DL policies. 17 metropolitan and provincial offices of education and agencies then implement tailored policy actions for local communities and districts. 2. During 2019-23, the MOE proposed 3 long-term DL national trajectories: -The 6th-Phase Master Plan for ICT in Education (2019-23) aimed for a human-centered approach, integrating intelligent technology. -The 2022 Revised National Curriculum emphasizes 'Digital-Based Innovation in Teaching and Learning'; The High School Credit System supported by the "Online Joint Curriculum" and the "ClassOn platform" provides personalized learning experiences and overcomes traditional constraints. - The 2023 Digital-Based Educational Innovation Plan caters to individual students' unique competencies and learning pace, utilizing AI Digital Textbooks, etc.	1. One-to-one computing program that provides students with their own computer or tablet to study. 49% of students in compulsory schools have access to this program (2018) 2. A national strategy to develop 'adequate' digital competence for students, teachers, and school leaders, develop collegial professional learning, appropriate technology, and sufficient IT infrastructure introduced by the Government (Since 2018). 3. A new national digitalization strategy covering 2023-2027 was proposed and sent out for consultation and audit in 2022. Based on the feedback, it paused in May 2023 because the strategy lacked scientific evidence.	1. Two key types of policy enhancing DL in primary and secondary schools: ICT infrastructure and enrichment of DL content. 2. The first type focuses on establishing robust information equipment and network infrastructure across campuses, containing 6 key policies from 1998 to 2025, e.g., developing computer classroom environment (1998-1999), providing mobile devices and internet connection (2022-2025), etc. 3. The 2nd type is to enrich digital learning content, with 5 key policies from 2001 to 2025; e.g., integrating technology into teaching and learning (2001-2007), enriching materials and educational big data (2022-2025), etc.	1. ICT for education policy has been continually developed and funded since 1967, supported until 2010 by the British Educational Communications and Technology Agency - Becta. 2. Two main policies before Covid-19: (1) Harnessing Technology in 2005, promoting e-learning strategies, and (2) Realizing the Potential in 2019, requiring schools to manage DL by themselves, in the context of the closure of Becta. 3. Three main DL-related programs: National Grid for Learning (1998) - providing digital resources; Laptops for Teachers (2002-05); and Building Schools for the Future (2003-10) - rebuilding the school estate & providing new ICT.	1. In 2015, the "Every Student Succeeds Act" program was implemented and one of the main aspects focused on technology and digital literacy, with less than 15% of allocation used for technology infrastructure. This program ensured government funding was allocated to school systems and local education agencies for DL. 2. The National Educational Technology Plan (NETP) in 2017 was considered the flagship educational technology policy for the U.S., promoting the needs for all in US education to ensure equity of access to transformational learning experiences enabled by technology. 3. Research and development for digital literacy in the U.S. is driven by government support and funding through various national centers. The newest R&D center, "Precision Education: the Virtual Learning Lab," focuses on personalizing and improving virtual learning.

Table 2 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Digital Learning Implementation in K-12 Schools	1. Digital Education Revolution (DER) (2011) was an initiative project providing DL support for high school students. 2. The National Innovation and Science Agenda aimed to improve digital literacy skills by funding projects at all schools, such as massive open online courses, digital technology challenges series, digIT series of summer schools. 3. Government and organizations (Education Services Australia, etc.) provide funding to support DL resources and safe online environments. 4. Research centers collaborate with government and non-government organizations, schools, and communities to enhance DL in curriculum development, assessment, teacher professional development, etc.	1. Digital technology (DT) had been integrated in the classroom, but it seemed to be limited. Teachers mainly gave students tasks where DT was only employed in a substitutional role. 2. Various digital interactive learning environments were used (such as Geogebra), along with video-based platforms (like YouTube) and gamified testing systems (Kahoot! and Quizziz). 3. Teachers revealed reasons to use DT, e.g., availability of appropriate content, students' easier access to learning tasks or content, greater ease to monitor the learning process & give feedback. 4. Differences in using DT among the 3rd, 6th, or 9th grades and math, science, & Estonian language classes, but not remarkable.	1. Finnish K-12 schools use various technology applications to enhance learning and teaching, e.g., educational apps, software, digital content and e-books. Less often used digital tools are related to coding and robotics, VR, AR and online assessment tools. 2. Finnish teachers and schools have great autonomy in teaching. The frequency of technology usage in the classrooms varies based on teacher preferences, available resources, and student age groups. 3. The most common use of digital technologies is for information search and processing. However, applications for promoting active learning, thinking-activating, and problem-solving tasks are rare.	1. The various statuses of DL in K-12 education depend on the specific conditions of each school. Schools may approve digital innovation more or less fast and often. 2. Among school types, DL is better in the gymnasium than in other schools. 3. Video, wikis, and standard office software were most often used by teachers. 4. The use of digital media in kindergarten is more sporadic and isolated from other educational concepts. 5. Primary schools have specific problems in gaining digital education, such as less money and lack of technical staff. Lower and upper secondary schools are supposed to use more differentiated digital device options.	1. DL has been implemented at all levels, all types of K-12 schools, and all learning areas. The government has provided support for schools to adopt DL, such as the provision of infrastructure and resources, teacher training, and curriculum development. 2. DL has been implemented more extensively in senior secondary schools by providing students with online courses, e-textbooks, and digital resources. More emphasis is on language learning, particularly for English and Chinese. 3. Major reasons are the increasing demand for personalized and flexible learning opportunities, the need to prepare students for public exams and further studies, and the importance of language proficiency in the globalized world.	1. The use of digital technology in education is more common and advanced in the later stages of education. 2. In kindergartens, digital technology is still in its infancy, limited to communication with parents. 3. MOE limits the amount of time children in kindergartens and grades 1-3 have internet access. 4. From elementary to high schools, the level of DL is mainly determined by individual teachers and the principal.	1. DL has fully integrated into the education system, spanning all school levels and learning domains. 2. Schools and students have access to a variety of national online learning systems that offer DL content across a wide range of subjects, catering to students of all grades and needs. 3. The AI Digital Textbooks Program will be implemented in phases from 2025, initially targeting selected grades in Math, English and Information Education. For example, it could support personalized learning in Math, utilize voice recognition to enhance English listening and speaking practice, and provide enriching coding education experiences and practical activities in information education learning.	1. Digital tools used at all education levels, such as VR, AR, multimedia, robotics, online assessment, etc. 2. In the 2018 National curriculum for compulsory and upper secondary schools, students were introduced to use digital tools in several subjects. 3. For example, preschool children use bots and tablets to learn basic programming, math and reading skills. 4. Digital learning materials covered all school subjects and are used by all students virtually in compulsory schools. 5. Data analytics for student learning in higher education is popular, but the application for K-12 is limited.	1. Many projects following "Promotion of Grades 1-12 School Digital Learning Enhancement Plan - 2021" were applied, promoting DL at all levels. 2. Digital instructional content was developed, focusing on each "subject" and "core competencies" in primary and secondary schools. 3. AI and Bigdata are applied to provide evidence of DL and students' learning analytics, supporting decision-making, DL platform adjustments, etc.	1. All levels and types of schools have some level of digital education. 2. Most primary schools have digital tools such as interactive smart boards, programming kits, etc. 3. Most secondary schools use free tools like G-Suite for Education or Microsoft Teams to communicate with learners, set tasks, and provide resources. 4. STEM education, computing curriculum, and coding have been invested in and developed for most students.	1. DL implementation in K-12 schools is ongoing with increased government support during the past decade. 2. There is limited technology use for young learners in early childhood and lower primary level. 3. Students start studying technology artifacts and other technology-based information at the upper primary level. Grades 4 and 5 employ more technologies than lower grades. 4. For the secondary level, students have more opportunities for DL, such as using smart devices in class, using LMS, enrolling in online coursework, etc. 5. Multiple technology tools for recordkeeping, assessment, and data reporting needed to support management are applied at all levels.

Table 2 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
The Impact of COVID-19 on Digital Learning	1. The impact was not uniform, depending on school location, the resources available, and the readiness of teachers and students for DL. 2. The rapid shift to remote learning in 2020 brought inequity and access issues such as the lack of digital devices and reliable internet access; it also caused problems with students' self-discipline. 3. The Government and schools subsidized home internet & device costs for disadvantaged students and improved internet connectivity in remote areas. 4. Schools started using LMSs and developing e-books and online resources, such us Google Classroom, Zoom, Microsoft Teams. 5. Online professional development and sharing forums support teachers in teaching DL. 6. Mental health and well-being of students during the pandemic was and still is a concern for staff.	1. In 2020, due to COVID-19, schools were forced to switch to online and hybrid learning. 2. Most teachers and students were ready to face the emergency because they had experimented with online learning during the e-learning days (self-studying at home with the digital material from teachers). 3. Factors impacted teachers' willingness to use online learning during Covid-19 are students' well-being, issues with the internet connection, lack of students' digital skills, and teachers' ability and beliefs.	1. With the support of the previous national promotion of education digitization, large-scale online education was urgently implemented during the epidemic. 2. Some schools had established a digital teaching culture in which various learning platforms and digital applications had been widely used by teachers and students. 3. The period highlights inequalities in digital skills and opportunities among individuals, schools and regions, and learning gaps in the wake of the pandemic. 4. Online continuing education and professional development courses have been offered to teachers for some time. 5. Informal peer support, like a forum or online discussion, has increased the most during the period.	1. In March 2020, all schools closed due to COVID-19, and the Digital Pact program became relevant. It had driven many teachers to engage with digital education and to use it frequently. 2. The national government provided 3 supplements of €500 million each to support online learning: one was the "Immediate equipment" that enabled schools to purchase devices, software licenses and carry out distance learning; another was to advance administration of equipment and services since many schools had a lack of specific competence and staff; the other provided teachers with mobile digital devices. 3. KMK published "Teaching and Learning in the Digital World" with a focus on the necessary digital school development processes and the qualification of teachers in didactic and technical terms	1. The strong DL infrastructure enabled K-12 education to rapidly transform to online teaching during the pandemic. 2. K-12 schools' e-learning was supported by funding from the Education Bureau. 3. COVID-19 period (2019 to 2021) increased students' time on digital technology, contributing to their digital literacy development. 4. Teachers adopted various asynchronous and synchronous digital technologies and instructional approaches for teaching, assessment, and communication with students and parents. 5. The pandemic has underscored the need for more effective digital learning strategies that can accommodate the interpersonal and social dimensions of learning.	1. IL successfully transitioned to distance learning due to several measures that were carried out before the pandemic. 2. Some advances made during the pandemic: distance learning policy and procedure, cloud infrastructure of learning materials for all educational institutions, systematic and orderly professional development for ICT teachers, etc. 3. 80-90% of schools used digital cloud infrastructure systems and DL content during COVID-19, and the number dropped to around 40-50% now. 4. Alternative assessments and online exams were also conducted.	1. While the pandemic has led to adverse outcomes, such as learning disparities and reduced student social-emotional aptitude, it has propelled a positive shift toward DL in schools. 2. From April 9 to 20, 2020, all students across the country started online courses utilizing blended learning approaches supported by 'The Handbook for Curriculum Operation.' 3. The MOE distributed smart devices, introduced public LMS platforms, & facilitated the establishment of wireless networks in all schools. 4. 'Operation Standards for Distance Learning' and 'Framework Act on the Promotion of Digital-Based Distance Education' were published by the MOE to assure DL quality. 5. Online teacher communities and training courses were established to support teachers in implementing DL.	1. Except for preschool, the other schools were carried out online with some offsite activities for a small number of students (March 2020) and hybrid education, a combination of onsite and remote teaching (July to October in 2020). 2. During that unprecedented time, a national hub for all school staff and teachers was set up rapidly to support them to find educational material, digital tools, and information.	1. Taiwan's education system was less disrupted by the pandemic compared to most countries worldwide (only 32 days of complete in-person class suspension) because of COVID-19 prevention and DL infrastructure. 2. The MOE had taken decisive steps before and during the COVID-19 outbreak to prevent disruption to students' learning, e.g., providing guidelines, DL platforms, tools, and resources for online teaching, and developing teachers' and students' proficiency in digital teaching and learning.	1. Covid-19 lockdown required rapid digital transformation for online learning at all levels with support from government agencies (funding and policy), the BBC (online videos), prominent IT vendors, charities, and all school stakeholders. 2. In primary schools, relevant work or videos were generally provided on school websites (or printed and sent out). Secondary schools often provided timely coursework and homework, with feedback via Zoom, Google Classroom, or Microsoft Teams. 3. Challenges faced by teachers: rapid shift to online learning, lack of digital access, adapting delivery for different needs, low level of digital literacy, online security & safeguarding, mental health and well-being.	1. COVID-19 abruptly changed the levels of DL for all U.S. K-12 schools 2. In the spring of 2020, 77% of public schools moved to online distance learning. By Spring 2021, 52% of public school students were enrolled in in-person instruction again. 3. Technology support for public schools was applied to provide students with digital devices, internet at home or other locations. 4. Educational systems moving to emergency remote learning was facilitated by offering digital or virtual learning opportunities via online video systems or LMS systems. 5. Virtual schooling application hads an 182.66% increase from 2013-14 to 2021-22 because of the pandemic. 6. The inconsistent digital access throughout the U.S. led to inequality of DL between city and suburban schools and high and low-income families.

Table 2 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Digital Learning Infrastructue	1. Every student has at least one computer, and 95% have access to devices in school; but technology infrastructure (TI) varies by school and location. 2. The government has strived to improve TI in connectivity and bandwidth. 3. Budget constraints led schools to adopt Bring Your Own Device policies, where students bring their own devices for classroom use. 4. Schools/educators have autonomy in shaping the design and delivery of digital content with ACARA's guidelines. LMSs are commonly used to support personalized and adaptive learning. 5. Data-driven interventions are used to monitor student progress and effectiveness of DL tools. 6. Organizations & schools provide training programs and for teachers' and staff's professional development. 86% of teachers feel confident using DT in classrooms.	1. All schools have adopted a Learning Management System to communicate among teachers, the school leadership team, students, and parents; it provides learning activities and tasks with interactive DL materials. 2. A considerable amount of money from the Estonian state budget and European structural funds has been allotted to build the structures and to provide digital technologies for teaching and learning. 3. Several courses/programs for pre-service and in-service teachers have opened to support educators' professional development for digital learning. 4. More than 2,000 digital learning materials have been systematized with free access to all teachers and students through an online repository called eSchool bag.	1. Schools have enough digital devices suitable for multiple uses, and the number of devices has been increasing systematically. 2. In 2020, over 50% of teachers owned personal laptops or tablets, and only 13% didn't have digital devices. The ratio of digital devices to students at schools varied from 1:4 to 1:12.5. 3. Among all devices, 3D printers and programmable robots have increased significantly. Three out of 4 schools have robots, and every second school has a 3D printer. 3. Almost all Finnish K–12 schools have well-functioning wireless network connections. 4. Schools and their leaders have a high degree of autonomy in leading a school's digital transformation and budgeting for developing DL infrastructure and updating devices.	1. The infrastructure at each school varies greatly and correlates to a large extent with the financial strength of the respective state & the responsible authorities. 2. Some pilot schools owned very advanced facilities. Conversely, only 57% of the teachers considered the equipment sufficient, 39% complained about the lack of a wireless LAN, 46% pointed out the poor internet connection (2021). 3. All funds of the "Digital Pact" are scheduled and committed, and the pact ends in 2024. 4. Some projects invested in developing the DL infrastructure, e.g., SODIX/MUNDO aiming at systematizing the open educational resources using AI, providing open access library; TBA aiming at providing assessment platforms, etc. 5. There are great gaps in the basic digital infrastructure of schools in 2022. Especially in primary and lower secondary schools, wireless LAN, learning management systems or networked collaborative tools are not available.	1. HK is a highly digitalized society. 90% of students had access to computers and internet at home in 2022. 2. The Government has made significant efforts and investments to promote schools' e-learning, such as establishing Wi-Fi campuses for 1,000 public sector schools to support digital classrooms, reviewing curriculums, fostering professional development for school leaders and teachers, enhancing the quality of e-learning resources, etc. 3. Primary and secondary school students demonstrated a high level of digital literacy in PISA results. Major stakeholders had positive attitudes toward DL at schools. 4. Many professional development courses on DL were organized by the Education Bureau's Web-based School Administration and Management System.	1. Substantial funding from the ICT program, and a special budget during COVID, enabled school administrators to flexibly select appropriate additional activities and infrastructure for DL. 2. 90% of schools have a techno-pedagogical or computation coordinator. 3. The online courses and LMS are used in many schools in both routine and emergency situations. 4. Virtual spaces like Springboard, Bagroup, and school curricula were designed to support students' success in DL. 5. The MOE has implemented a digital testing format for the matriculation exams. 6. Various channels and courses are designed to support the digital professional development of teachers and staff. 7. Students and teachers are governed by a password-based information security mechanism.	1. Since 1996, Korea has been steadily establishing and enhancing digital infrastructure for teaching & learning. 2. The "Master Plan for ICT in Education" is executed every 5 years, providing policies and funding for DL development. 3. Various DL platforms have been promoted to support flexible learning experiences, catering to the unique needs of each group, such as transferred students, student-athletes, adult learners, students with disabilities. 4. The ratio of digital devices per student from 2020-22 increased from 0.2 to 0.34. Students' digital competencies continued to improve. 5. MOE provided "The Student Evaluation Support Portal" to enhance teachers' evaluation expertise, and used "The National Education Information System" to facilitate administration across all schools. 6. Several teacher professional development programs offer teachers the flexibility to choose customized courses based on their preferences and needs.	1. A national hub provided free digital resources for teachers and students. 2. Laptops and tablets provided for students by the One-to-One computing program. 3. Quick internet or Wi-Fi connection is available in all schools. 4. No central coordination of basic IT standards. 5. During the last 5 years, several activities related to digital infrastructures have matured, such as IT standards for a smooth digital ecosystem, a forum for information standards educational technology map. 6. A master's program in Educational Technology has been offered. 7. In 2018, 3.7 billion SEK was invested in educational technology.	1. Substantial budgets were allocated to promote DL, e.g., 20 billion NTD for the "Promotion of Grades 1-12 School Digital Learning Enhancement Plan" from 2021 to 2025. 2. Following that plan, technology infrastructure for DL has been ensured since 2022; e.g., Internet access and tablet use for students from grades 1-12. 3. The MOE launched the "digital learning guidance team" (including central and local teams) in 2019 to efficiently manage and implement DL. 4. TALP, the official platform endorsed by the MOE, is the core environment for students' DL. It provides both teaching material and assessment platforms, significantly impacting students' learning outcomes. 5. A national digital teaching guide was published in 2022 to help teachers systematically use digital tools, teaching materials, and support training sessions to enhance digital teaching capabilities.	1. In general terms, each school in England has good technology infrastructure, such as broadband connection to the internet, devices, electronic whiteboards, tools, apps, etc. 2. Funding and support is decentralized, with different types of solutions in different geographic areas and for different types of schools. 3. Some schools provide good examples of digital policy on remote learning and library strategies to support digital literacy. 4. Lesson delivery via whiteboard is a dominant pedagogic approach, presenting in over 90% of classrooms in Britain. 5. Teachers can develop their digital skills using online courses, such as FutureLearn, EdTech, etc.	1. The infrastructure of public schools is supported by diverse federal acts, laws, and local initiatives. However, the equity in the availability of DL assets varies by state and locality. 2. Flexible infrastructure is used by some school systems to promote agility in spending technology funding by promoting openly licensed educational resources and sharing these resources with other systems. 3. In 2021, 45% of public schools had one computer per student, 34% assigned computers for in-school use, and 15% allowed students to take computers home. A 3% increase in 1:1 device programs occurred from 2021 to 2022 to enhance student device availability. 4. Most schools have good internet connectivity, but gaps persist in remote/rural areas. 5. The DOE issued digital leadership guidance for school leaders to promote the adoption of DL. It assists in planning, funding, implementing, and adapting programs to meet the unique needs of students & teachers in DL.

Table 2 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Features of Digital Learning	1. One technology curriculum for all Australian students: all students study Technology and Digital Literacy from Foundation-Year 8. 2. The General Capabilities, especially DL literacy, provide topical and authentic material for students to discuss the issues surrounding technologies and their lives and future careers. 3. Emphasizing safety and digital citizenship education. 4. Compulsory coding and computational/system/design thinking skills for all students from Year 3 and above.	1. Developing digital competence for teachers and students is focused on. 2. A significant shortage of teachers motivates policy-makers to urge them to apply technology in teaching for sustaining the quality of education and reducing the workload. 3. Educational decisions in Estonia are guided according to the contemporary learning approach that enhances the role of digital learning in all steps.	1. Finnish students rank top three in computational thinking among ICILS countries, with girls outperforming boys. 2. Socioeconomic differences, such as parents' education and occupation, and the number of books at home, significantly impact Finnish students' ICT skill levels. 3. Finnish youth use ICT devices for learning less than youth in other countries. 4. More systematic research on K-12 schools' DL in FI is needed to understand the current situation and future vision.	1. The curricular freedom of any single school in K-12 education. 2. The freedom to teach subjects with different degrees of intensity and in different grades (digital education classes). 3. A huge amount of money has been invested to fund digitalization in schools.	1. A high degree of digital competence increasing at a rapid pace. 2. Nurturing students' higher-order thinking skills. 3. Encouraging parental involvement	1. Strong foundation for the use of digital records. 2. Advanced school data management. 3. Strong connection between the MOE and the academic community.	1. The national-level Master Plans for ICT (since 1996) allow continuous progress in DL and effective responses to unforeseen events. 2. A strong emphasis on providing diverse training opportunities to enhance teachers' competencies. 3. Develop learner-centered platforms to ensure students' right to education & meet diverse learning needs. 4. AI digital textbooks have emerged as a significant medium for DL in public education. 5. The school's high-speed internet connection and advanced ICT infrastructure support the implementation of DL initiatives.	1. Students from low-income families may not have access to the technology and resources. 2. Inequalities led to the gap in digital literacy among groups of students. 3. Schools could create personalized and engaging learning experiences catering to each student's needs.	1. Giving priority to subsidizing mobile devices for schools in remote areas; developing a free and robust learning platform to ensure learning equity and prevent students' dropout. 2. Enhancing adaptive learning and promoting self-regulated learning through collaboration. 3. Leveraging educational big data and AI.	1. Elective Home Education (EHE) - home-schooling - is a personal choice and parents do not have to teach a mandatory curriculum or register their child. 2. Virtual home-schooling is adopted whereby many parents provide a formal curriculum via online schools, resources, or tutors. 3. Wide range of systems and devices. Teachers use over 50 different ICT systems. 4. Digital K-12 in England is isolated from universities, from each other (no central agency or regional aggregation) and from other countries, especially Europe, in terms of training, research, structure, support and procurement.	1. Blended learning is becoming a strong presence in U.S. educational settings. 2. Digital curricula and resources are used to enhance learners' DL experience. 3. Learning analytics is applied to personalize the instruction and learning environment. 4. 1:1 device initiatives equip students with digital devices for DL. 5. Digital privacy policies safeguard the privacy of students and educators as using online resources

A Comparison of Trends and Issues in Digital Learning

This section provides a summary and discussion of the trends and issues in DL across the 11 countries, in terms of the above components and elements, such as policies, implementation, and features of DL. In this context, the term "trend" is defined as the general direction in which DL in K-12 is developing or changing, while an "issue" refers to an important topic or problem in promoting DL for debate or discussion. The trends and issues for the 11 high-digital-competitiveness countries are compiled in Table 3.

Component 8: Major trends in digital learning

Figure 3 presents a word cloud generated from the descriptions of major trends in DL in the country reports. Several trends were highlighted across the countries. First, the widespread adoption of AI to support students' learning is a popular trend in many countries (AU, EE, KR, SE, TW, US). AI applications are carried out through various tools, such as ChatGPT (SE) and adaptive testing and teaching (AU, TW, US). AI learning platforms have also been developed and implemented in DE, KR and TW. Obviously, there is a growing application of generative AI in K-12 education.

Figure 3 A Word Cloud of Major Trends in Digital Learning in the 11 Countries

The second trend is the enrichment of game-based digital learning, observed in AU, TW and the US. This learning approach has potential to engage and motivate students, enhancing their knowledge as well as problem-solving and critical thinking skills. The third trend is a growing use of data and learning analytics from LMS to provide feedback to students and support decision-making and instruction (FI, IL, US). Apart from AI, games, and data analytics, technologies such as virtual reality/augmented reality (US), and testbeds (SE), e-sport (AU), and digital collaboration tools (AU) are also highlighted in the word cloud.

The fourth trend involves the promotion of personalized learning through the utilization of digital tools that customize learning content, feedback, and activities to cater to the needs and abilities of individual students (HK, SE, US). This personalized learning approach is also anticipated to enhance students' autonomy and self-regulated learning abilities. The fifth trend is the increasing importance of digital competence, with many efforts focused on fostering DL competencies among both teachers and students (AU, EE, FI, KR).

Furthermore, the sixth trend is the development of core competencies in computational thinking skills, creative thinking and flexibility, with the support of DL processes (FI, TW). The seventh trend highlights the necessity of preparing students for a digital world, proposing the integration of emerging informatics, programming, and coding courses into students' curricula (AU, DE, SE, US). The eighth trend involves updating teacher education programs and introducing intensive teacher training courses for DL (DE, HK, IL). The ninth trend is the development of teachers' communities to share and support in-service teacher digital teaching, as observed in EE and KR, and creating a pedagogical database for DL (IL). The final movement is observed in many countries with a focus on developing diverse options and resources for supporting DL in schools (EE, FI, DE, HKIL, SK, SE, UK, US). Some unique trends are also found in each country, such as developing STEM education (AU), changing DL school culture (DE), opening of the Jewish Orthodox society to the digital world (IL), and digital exams (UK).

Component 9: Major issues in digital learning

The 11 countries have recognized the importance of digital learning in the contemporary education environment and have made significant efforts to promote it in K-12 education through various forms of access. However, several problems and topics have been raised for debate or discussion (see the word cloud in Figure 4). Below are six issues commonly addressed by these countries.

Figure 4 A Word Cloud of Major Issues in Digital Learning across the 11 Countries

First, there is a lack of clear vision, long-term planning, or guidance for the effective implementation of digital learning (EE, FI, HK, IL, KR). Despite DL having been widely adopted in these countries, the absence of a vision with quality-oriented learning goals and macro-level planning for DL implementation poses challenges for schools and teachers in delivering effective digital education. Some countries lack clear guidance to support teachers' teaching in DL environments, such as integrating new digital competencies into their courses, assessing student performance, and collecting data in online learning settings.

The second issue is related to teacher shortage (AU, EE, DE) and insufficient digital competencies (AU, FI, KR, TW, US). Teacher shortage is a barrier to effective digital teaching, as the high workloads limit teachers' time to prepare digital materials and employ digital teaching methods. These approaches, especially for personalized learning through DL platforms, are often time-consuming. The reasons for teacher shortages in AU are identified, encompassing declining numbers of pre-service teachers, population increase, and teacher burnout. To mitigate its negative impact on education quality, several solutions have been implemented, including providing scholarships for pedagogical students and improving teachers' working conditions.

Regarding teachers' competencies, a significant variation in digital teaching skills is noted, underscoring the need for digital pedagogical training programs for in-service and pre-service teachers (FI, KR, SE, TW, US). In TW and AU, recommendations for teachers' professional development activities related to the application of AI in teaching include workshops, online courses, webinars, or peer-led training courses. FI suggests leveraging learning experiences from peers and communities, and also advocates for the development of innovative and effective DL tools and materials.

Third, the lack of funding and digital infrastructure poses challenges in promoting DL (DE, IL, US). DL requires significant support from modern digital tools and infrastructure, often involving substantial investments (Davis et al., 2008). The investments, however, may vary by state and locality due to federal acts, laws, and local initiatives (e.g., DE, US). For example, in GE, states with better financial situations can allocate more funds for digital infrastructure, similar to the US, where school funding varies and heavily relies on local support. In IL, significant disparities between different socioeconomic and ethnic groups also result in a lack of infrastructure in certain areas. Furthermore, discontinuing funding for DL after the COVID-19 pandemic raises concerns about the maintenance of DL tools and devices.

The next issue relates to the inequity in access to DL resources among students (AU, DE, HK, IL, SE, US). The aforementioned differences in funding allocation among schools lead to variations in access and use of digital resources (DE, US). Concerns about the DL inequity among minority students are also raised in the US, particularly for those with disabilities, special needs, or language barriers who require specialized technologies to support DL. In

HK and SE, students from disadvantaged backgrounds or rural areas may face challenges due to a lack of digital devices and internet connectivity at home, hindering their participation in distance education and access to online resources. To address this issue, various programs have been implemented to provide students with computers for use at home, such as the Computer Recycling Scheme in HK, the One-to-One Computing Program in SE, Bring Your Own Device in AU and Take-Home Student Device in TW. However, it is important to note that not all students can participate in these programs.

The fifth issue concerns the data security and ethics in online learning (DE, KR, SE, TW). As the use of data to manage student learning becomes a trend in many countries, there is a growing need for clear plans and policies to protect students' and teachers' information from third parties (HK, GE). Additionally, the emphasis on students' mental health in online environments has increased, considering the risks associated with a lack of real interactions and excessive screen time (HK, KR). Hong Kong has updated the "Information Literacy for Hong Kong Students' Learning Framework" to include more guidelines to address these issues. The lessons from AU's "Online Safety and Digital Citizenship Education" could serve as a reference.

The final issue relates to assessment in online learning. In HK, IL, and SE, high-stakes examinations dominate teaching and learning in schools, leading teachers to focus on content that aligns with exam requirements rather than using constructivist DL approaches (IL). In addition, when conducting formative online assessments, poor internet connections or limited resources may impact students' test results, resulting in inequalities among students. Another concern involves cheating in online assessments (HK, IL, SE), where students may support peers during tests through online chat or using AI applications like ChatGPT to find answers. These situations highlight the need for research on digital assessment to leverage the advantages of digital tools in online learning assessments.

In summary, DL has gained significant attention and progress in all 11 countries, receiving strong support from governments and societies, particularly during the COVID-19 pandemic. It has been implemented across all levels of K-12 education with varying degrees of success, and the levels of digital transformation differ among countries, states, and schools. Despite the challenges presented, a series of examples and experiences shared by these countries can offer potential solutions and lessons for other countries seeking to enhance their digital transformation capabilities. The proven effectiveness of DL represents a major advance in these countries and beyond, playing a vital role in preparing the workforce for a digital future.

Table 3 A Summary of Trends and Issues in Digital Learning

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Major Trends in Digital Learning	1. The integration of technology in all aspects of the education system 2. The growing importance of DL for both teachers and students 3. AI utilization is gaining popularity in teaching and learning 4. The rise of integrated STEM education 5. The increased use of computer games, gamification, and eSports 6. Using DL tools for collaboration	1. Digital technologies are actively used in most classes, even if the purposes and ways of the usage are limited. 2. DL is characterized by constructive assignments where students need to integrate their preknowledge with new content without interaction with other learners. 3. The digital competence of learners and educators is highlighted as an important general competence in strategic documents. 4. No major restrictions or impediments hinder DL in schools. 5. Teachers' professional development is organized as an activity of professional communities.	1. An emerging digital revolution 2. The growing use of data, development of algorithms, increased computing capacity, and interconnectedness 3. The importance of digital, technological, and information literacy is increasing. 4. Learning analytics for collecting evidence of learning progression and for providing feedback channels for learners and teachers. 5. Supporting human learners' unique skills of creative and flexible thinking.	1. Teachers' interest in DL is rising. 2. There is a change in the use of digital services in school culture. 3. Digitalization delivers options for diverse groups. 4. Informatics is emerging as a growing subject in schools. 5. Teacher education and further education are being renewed.	1. More sophisticated and diverse use of DL. 2. Promotion of autonomous and personalized DL. 3. Ongoing development of initiatives on DL. 4. More intensive teacher training. 5. Ongoing curriculum transformation and development of school plans.	1. A dramatic improvement in physical digital infrastructure. 2. Building a pedagogical database for digital transformation. 3. Moving toward digital data management and decision making. 4. Acceleration of digital use in teacher education. 5. Gradual opening of the Jewish orthodox society to the digital world.	1. Integrating artificial intelligence in DL. 2. Offering diverse DL resources. 3. Fostering teacher communities for strengthening DL competencies. 4. Expanding software and AI literacy education for both students and teachers. 5. Expanding online learning spaces	1. Increasing use of digital technology 2. Focusing on personalized learning 3. Assessing digital learning through testbeds 4. Promoting programming learning 5. Making room for generative AI	1. A growing application of generative AI. 2. Using AI tools for adaptive teaching. 3. Leveraging digital technology to strengthen core competencies. 4. Enrichment of game-based DL. 5. Deploying innovative policies, e.g. "Bring Your Own Device" and "Take-Home Student Device" for DL engagement.	1. Increasing bandwidth to each school and pupil, at school and at home. 2. Increasing numbers and power of devices used. 3. GCSE and A level exams remain predominantly paper-based but are starting to change. 4. Virtual schools are growing but are still peripheral. 5. Increasing role for centralized and open content.	1. Developing online learning options in the school systems. 2. Enhancing personalized learning 3. Fostering coding and computer science education. 4. Fostering gamification and game-based learning 5. Expanding the usages of AR, VR, and AI. 6. Rising data-driven decision making and instruction

Table 3 (continued)

Component	Countries										
	Australia (AU)	Estonia (EE)	Finland (FI)	Germany (DE)	Hong Kong SAR (HK)	Israel (IL)	Korea (KR)	Sweden (SE)	Taiwan (TW)	United Kingdom (UK)	United States of America (US)
Major Issues in Digital Learning	1. General teacher shortage 2. The need for teacher professional development 3. Uneven access to DL: the digital divide 4. Community pushback against digital technology use 5. Lack of engagement with DL by Australia's First Nations students	1. Schools and teacher communities often lack a clear vision of the meaningful use of digital technologies. 2. Teacher shortage is placing higher demands on teachers in terms of coping with the challenges of personalizing learning for students with different needs. 3. Strategic documents do not guide teachers towards more professional development to improve their contextual and transformative digital competence. 4. Students need more guidance towards the effective use of digital technologies for learning. 5. More research is needed to support digital transformation.	1. Digital technology is rarely used in K-12 schools for activating thinking or inquiry-oriented and collaborative ways. 2. Finnish students adopt most of their ICT skills outside of school. 3. A large variation in teachers' skills and willingness to implement digital learning. 4. Teachers' pedagogical autonomy should not overshadow students' rights to acquire the digital skills. 5. The lack of algorithmic awareness can negatively affect the possibilities for societal participation. 6. A clear need to guide all teachers in integrating computational thinking into their teaching.	1. Innovation in education is very time consuming. 2. A lack of teachers, especially in the STEM subject. 3. Limitations due to data protection. 4. Funding is in question. 5. The distribution of funds is unfair.	1. Lack of concrete plans or systematic implementation on ethical and healthy use of digital technology 2. A growing concern about the adverse effects of digitalization. 3. Challenges in assessments for DL, such as no systematic guidelines or evaluation criteria, cheating in high-stakes tests, inequity for disadvantaged students, etc. 4. Widening the digital divide among K-12 students. 5. Lack of long-term planning by the Government	1. Conservative perceptions of the educational process. 2. Lack of understanding of the potential of digital education. 3. High-stakes examinations dominating the teaching, assessment and learning activities. 4. Insufficient incentive for digital education content creators. 5. The fractured nature of the Israeli society and Israel's education system in particular. 6. Lack of infrastructure and culture of digital use in education in some populations.	1. Widened learning disparities during COVID-19. 2. Lack of clear guidelines on student data 3. Ethical issues of AI in education 4. Challenges in teachers' digital competency development 5. Insufficient socio-emotional support	1. Increasing digital equity for all 2. Lacking digital skills and training 3. Ensuring educational data security 4. Evaluating learning by digital assessment methods 5. Growing need to teach digital citizenship	The following efforts have been made to overcome challenges: 1. Enhancing the capability of primary and secondary school teachers and students to use AI-driven tools in teaching and learning. 2. Enhancing digital literacy for education stakeholders 3. Creating a sustainable DL environment. 4. Ensuring data accuracy, comprehensiveness, and representativeness for data-driven decision making in educational policies. 5. Creating adaptive learning for inclusive education.	1. Continued structural disorganization in the school sector with only small signs of progress. 2. Signs of convergence of Sixth Form Colleges with post-secondary in ICT terms, leading to a more "university-like" approach to systems. 3. Unclear role of home and parents in digital learning. 4. Resistance to change the school day or year to facilitate or exploit digital learning. 5. Growing use of AI and other advanced technologies in schools.	1. The inequity of accessing DL resources. 2. Lack of connectivity or engaged creative DL. 3. Equity and inclusion concerns for disabilities or students with special needs. 4. Lack of teachers' professional training for digital education 5. Lack of funding for school DL infrastructure.

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