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 com-

prehensive 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, preelementary, 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

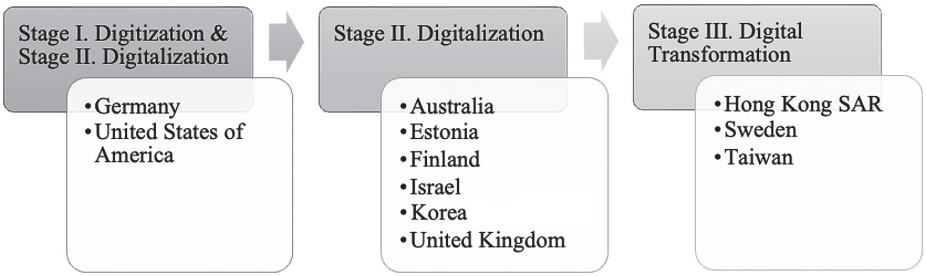

Table 1 Summary of Schooling System and Stage of Digital Transformation in K-12 Education across 11 Countries

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 im-

plementation 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) - homeschooling - is a personal choice and parents do not have to teach a mandatory curriculum or register their child. 2. Virtual homeschooling 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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