United Nations Educational, Scientific and Cultural Organization

Mahatma Gandhi Institute of Education for Peace and Sustainable Development

RETHINKING PEDAGOGY

EXPLORING THE POTENTIAL OF DIGITAL TECHNOLOGY IN ACHIEVING QUALITY EDUCATION

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Exploring the Potential of Digital Technology in Achieving Quality Education

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Cultural Organization

Mahatma Gandhi Institute
of Education for Peace
and Sustainable Development

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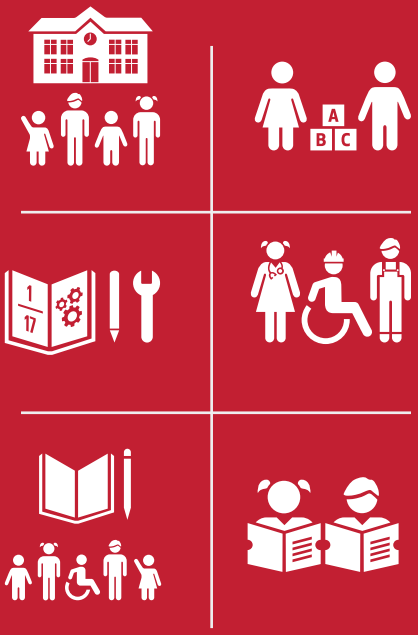
Sustainable Development Goal

4 QUALITY EDUCATION



Ensure inclusive and equitable education and promote lifelong learning opportunities for all

United Nations, *Transforming Our World: The 2030 Agenda for Sustainable Development*, 2015

Director's Message

The Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP) is UNESCO's Category 1 education Institute in the Asia-Pacific region devoted to education for peace and sustainable development, as enshrined in SDG Target 4.7. UNESCO MGIEP promotes the use of digital learning platforms where teachers and students can co-create and share a highly interactive learning experience. With the rise of the internet, there has been a proliferation of online content and digital resources intended to support teaching and learning, albeit widely varying in quality. Digital education media and resources, if carefully designed and implemented, have a significant potential to be mobilized on a massive scale to support transformative learning for building sustainable, flourishing societies.

In considering its contribution to SDG Target 4.7, which focuses on education for peace, sustainable development and global citizenship, UNESCO MGIEP has called for exploring the possibilities of digital pedagogies as an approach to reach and connect the millions of learners across the world and scale up transformative learning. This report focuses on bringing to the fore what we do and do not know about digital education and the gaps in research and practice we need to address, drawing from a body of knowledge about the role of digital technology in education (academic and policy literature review), the mapping of existing digital textbooks and other digital education media and resources (review of existing digital resources), and examples of implementation of digital education initiatives from around the world.

It is hoped that this global review of digital textbooks and other digital education media and resources will help highlight the potential of digital technology in contributing to quality, inclusive, and equitable education. There is a real potential to change patterns of relationships in learning with digital technology: learners as knowledge producers, collaborative peer learning, and learning analytics for student assessment, among other innovations; but we must do this right by drawing from the most relevant and credible literature on the subject.

Digital technologies have a potential to facilitate a long-desired shift from learning as passive content acquisition to learning as active knowledge co-creation and communities of practice. Integrated digital education media are envisaged to provide personalized, immersive learning experiences that allow interaction and collaboration going beyond the constraints of the four walls of the classroom and the cells of the school timetable. They might also allow for easier and faster updates of content and the presentation of information in user-friendly formats, enabling the content to remain relevant and highly engaging for enhanced learning outcomes.

How can we better understand and harness pedagogical possibilities opened up by new digital technologies to equip young people with competencies to engage creatively and responsibly with the rapidly changing world? How can we use technologies to make school education not only more inclusive and of higher quality but also a key enabler for sustainable development? Can digital technologies provide individualised learning catering to the strengths of each learner while understanding and addressing the areas for improvement? This report attempts to start a dialogue between digital education proponents and SDG 4 stakeholders around these important questions.

Anantha Duraiappah
Director, UNESCO MGIEP

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The international expert group members commenced working on the global review of digital textbooks and digital education media and resources during the first drafting group meeting in July 2018, which was organized at Braunschweig, Germany, with the kind support of Georg Eckert Institute for International Textbook Research and Engagement Global – Service für Entwicklungsinitiativen (Service for Development Initiatives). It was followed by the second drafting group meeting at UNESCO MGIEP's annual conference TECH in Visakhapatnam, Andhra Pradesh, India in November 2018. The third and final drafting group meeting was held at UNESCO Headquarters in Paris, France, in May 2019.

We would also like to acknowledge with much appreciation the Ministry of Education and the Ministry of Training, Colleges, Universities and Secondary Education Teachers in Ontario, Canada, the Ministry of National Education, Childhood and Youth of Luxembourg, and the French Ministry of Education for their support in sharing digital education resources.

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Acronyms

AI	Artificial Intelligence
AR	Augmented Reality
CC	Creative Commons
DQ	Digital Quotient
EdTech	Educational Technology
EFA	Education for All
EMIS	Education Management and Information Systems
ESD	Education for Sustainable Development
EU	European Union
GAFA	Google, Amazon, Facebook, Apple
GCED	Global Citizenship Education
GDPR	(EU's) General Data Protection Regulation
ICT	Information and Communication Technologies
ICT CFT	(UNESCO's) ICT Competency Framework for Teachers
ISTE	International Society for Technology in Education
IT	Information Technology
K-12	Kindergarten to 12th grade (a short form for the publicly-supported school grades prior to college)
LAUSD	Los Angeles Unified School District
LMS	Learning Management System
MEC	Ministério da Educação (Brazilian Ministry of Education)
MGIEP	Mahatma Gandhi Institute of Education for Peace and Sustainable Development
MIT	Massachusetts Institute of Technology
MOOC	Massive Open Online Course
OECD	Organization for Economic Co-operation and Development
OERs	Open Education Resources
OET	Office of Educational Technology (in the Office of the Secretary of the U.S. Department of Education)
PCV	Peace Corps Volunteer
SDGs	Sustainable Development Goals
SIDS	Small Island Developing States
STEM	Science, Technology, Engineering and Mathematics
UC	University of California
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.K.	United Kingdom
U.S.	United States
VR	Virtual Reality

Executive Summary

With the exponential growth of digitally mediated communication, digital media and gaming, the landscape of what we understand as learning environments is changing significantly. Today the use of digital technology in education is attracting considerable public and policy attention as well as private investment. With a rise in discourses both heralding and cautioning against the use of digital technology in education, there is a need to pool the expertise and experience on the use of technology in education from around the world to advance public debate and evidence-informed policymaking.

Based on the literature review, mapping of digital education resources in circulation, and examples of implementation of digital education initiatives from around the world, this report aims to provide insights that would help lead to the wise, innovative and ethical use of digital technology in education as a new dimension in achieving SDG 4 — inclusive and equitable quality education and lifelong learning opportunities for all. By so doing, it also attempts to contribute to a rethink of teaching and learning in the face of enormous opportunities and challenges brought about by digital technology in the times of change and turmoil.

Process and Structure of the Review

The **Global Review of Digital Education Media and Resources** was conducted over the period of 15 months from July 2018 to October 2019, involving more than 30 international experts convened by UNESCO MGIEP. This report focuses on bringing to the fore what we know and do not know about digital education and the gaps in research and practice we need to address.

The review was based on three major components: (1) a review of a body of knowledge about the role of technology in education (academic and policy literature review), (2) the mapping of existing digital textbooks and other digital education media and resources (review of existing digital resources), and (3) examples of implementation of digital education initiatives from around the world (case studies). These three components together portray an organized 'state of the art' of digital education resources, informed by history and contrasting examples of their implementation in different settings.

Close to 300 references, including books, academic articles and research and policy reports, in the fields of textbooks and educational media, computer science, learning science, comparative media studies, distance education, educational technology, digital media and learning, gaming and learning, artificial intelligence, among others, were consulted for a critical review, synthesis and analysis of literature on the role of technology in education (Chapters 2, 3 and 4). The international expert group convened by UNESCO MGIEP sampled more than 80 digital education resources, including repositories of Open Education Resources (OER), Massive Open Online Course (MOOC) platforms and Learning Management Systems (LMS), which served as a basis for developing a typology of existing digital education media and resources (Chapter 3 and Appendix I). The report also analyzed case studies of implementation of digital education initiatives from different continents, including Europe, Asia and the Pacific, Americas, and Africa, to help us better understand nuanced differences and factors involved in implementation (Chapter 5).

UNESCO MGIEP organized three drafting group meetings in Germany, India and France over the course of one year. Conscious efforts were made to include non-English language literature and resources in the review. The report was finalized after reflecting comments from the Peer Review Group comprising five prominent experts in the broad field of education media and digital learning. Successive drafts also benefitted from feedback provided by a number of stakeholders in the public and private sectors and civil society.

Aims, Scope and a Guiding Framework

As a contribution to SDG 4, the review was conducted with a primary focus on K-12 education, particularly compulsory education, with a secondary focus on higher education and lifelong learning contexts. The review covered the use of digital technology as

1. an **educational technology**,
2. an **instrument at the heart of the disciplines taught** (e.g., dynamic geometry, geographic information systems, language translator),
3. **ICTs** for organization, communication and investigation of tasks in the classroom and at home, and
4. **a new subject area** to teach knowledge and skills needed to create digital solutions to emerging and persistent challenges of our society (e.g., computational thinking, coding and programming skills).

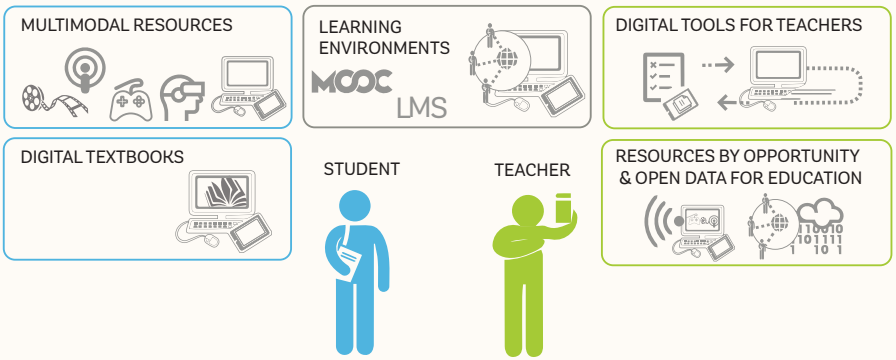
Corresponding to these four faces of digital technology in education, the review addressed issues around building required **competences of educators** to respond to the increased use of digital technology in education.

1. **Technical changes** refer to changes in the required technical competence of teachers, such as knowledge and skills to use digital devices (e.g., computer, whiteboard and tablet as instruments).
2. **Instructional changes** refer to changes in subject-based teaching competence.
3. **Pedagogical changes** refer to changes in pedagogy that transcend subject boundaries. The increased use of digital technology — inside and outside of classrooms — has implications on appropriate modes of intervention in the classroom and practical management of teaching-learning activities.
4. **Epistemological changes** refer to changes in the very objects of teaching and learning. The increased use of digital technology — in education and in society — calls for rethinking of the underlying systemic aims of education.

Key Findings

Instruments: Design and typology of digital education media and resources

1. **New technologies coexist and hybridize with old and established educational technologies, including textbooks.** Tracing the evolution of the textbook in relation to 'teaching machines' on one hand and 'electronic books' and hypertext on the other, the literature review shows that textbooks (and books more broadly) have always incorporated elements of the new technologies of their time.
2. **Digital technology is opening up learning resources from past conventions and limitations.** Whereas scholarly and policy work on open education has focused mainly on higher education, there are promising examples of using OER in compulsory education. Digital technology is changing the mode of production of textbooks and facilitating the local contexualization of content and teacher participation in the creation of textbooks.
3. **Digital technology has made strides in building low-cost and universally accessible education media and resources**. A review of diverse digital resources sampled, both OERs and commercial products in circulation, formed a basis of a typology of digital education media and resources:
   - i. **Digital textbooks**: This category concerns resources related to academic education covering the notion of textbooks (with one or more levels and focusing on a single subject/ discipline).
   - ii. **Multimodal resources**: This category concerns tools that can be used at different levels relatively independently. These can be tools associated with a particular discipline (such as mathematics), collections of tools, e-books or resources, or a portal providing access to a plurality of resources such as videos, simulations, games, animations and mobile device applications.
   - iii. **Learning environments** (teacher-student interaction spaces): Examples include MOOC platforms, social networks sites, and LMS.
   - iv. **Digital tools for teachers**, such as lesson plans, assessment or evaluation tools: Some specific assessment tools are not for teachers but for institutions at sub-national, national or international level.
   - v. **Resources by opportunity and open data for education**: This category covers resources that were not initially designed for use in a teaching context but teachers decide to use for educational purposes, along with open data for education, which is important in the context of monitoring progress towards achieving SDG 4.



Pedagogy enabled or facilitated by digital technology

1. **Many available digital resources can support open pedagogy.** Not only has technological advancement enabled new ways of presenting, archiving and interacting with content, it has also allowed new ways of creating and sharing content. New digital technologies lower barriers to creative expression and powerfully support participatory and collaborative learning and co-creation of knowledge.
2. **There is a tension between a mechanistic view of learning and a more holistic and humanistic one underlying the design and use of digital technology in education.** This is reflected in a tension between the mass customisation models of differentiated or personalised technologies and an aspiration to enable more diverse and open-ended learning. There is an increasing emphasis on making learning more predictable and effective through accurate prediction and feedback adaptively delivered by machine learning algorithms, while there is a competing aspiration to enable everyone to access a world of abundant information, rich expertise and resources, according to one's interests.

Implementation and use

1. **Some of the most successful digital education resources, in terms of circulation and use, are 'production' or 'construction' software such as *Scratch*, *Minecraft*, *Code.org* and *Geogebra,* which allow the development of projects and scenarios by users.** These are multimodal resources that can be used relatively independently. Code.org, with more than 56 million projects (resources) created on the platform (as of 21 October 2019), offers a good example of activities that can only be done using digital technology.
2. **Some instructional software — including intelligent tutors — are also widespread and have been proven scientifically to 'work', but mainly limited to some disciplines such as mathematics and computer science.** The literature review and the mapping of digital resources suggest that digital education resources work best in problem domains where highly structured progressions are possible, such as algebra. Digital resources in the form of 'just-in-time' 'how to' video tutorials also work well for plain know-how and simple technical skills, but both intelligent tutors and video tutorials are less applicable in subject areas where progression cannot readily be assembled into a linear sequence of knowledge components or learning domains where competences cannot be easily measured, including so-called 'soft skills' and '21st-century skills'.
3. **There is growing evidence that MOOCs and similar approaches to online learning tend to exacerbate disparities in educational outcomes related to socioeconomic status, both within and across countries.** There is little evidence to support that going digital improves learning outcomes, cuts costs or reduces inequalities. In contrast, given the rise of online learning in general and MOOCs in particular, large-scale studies with robust designs have become possible, pointing to the negative equity implications of online learning (Hansen and Reich 2015; Kizilcec et al. 2017). This is confirming the long observed trend that new technologies tend to be used and accessed in ways that benefit privileged learners and widen disparities (Reich and Ito 2017).
4. **Teachers remain key actors.** Research highlights the key role of teachers in ensuring the effective use of digital resources. For example, research on the implementation of mathematics and reading software in U.S. schools showed that the use of software-generated student performance data was one of the largest differences between high-gain and low-gain implementations of instructional software, and also in terms of managing the classroom effectively. The study concluded that teachers should be urged to capitalize on the assessment data that instructional software makes available and that training and support around instructional software should pay more attention to the details of classroom management (Means 2010).

Key Messages

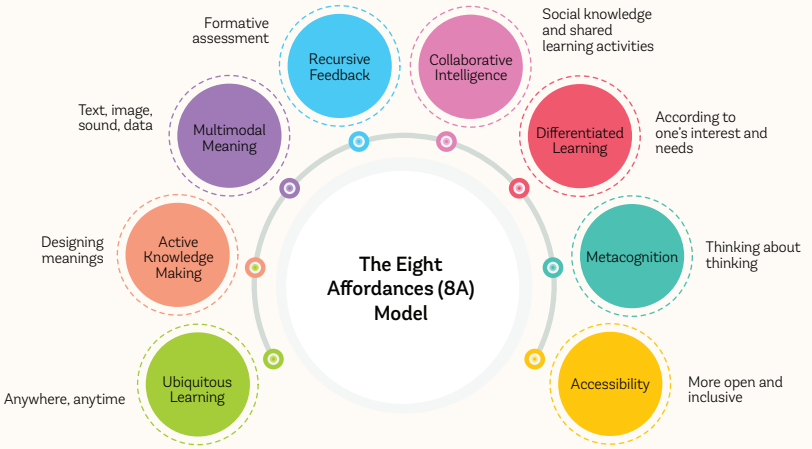
Education is not only a technical issue but essentially about a vision of what kind of world we want to live in. To understand what is at stake and support a transformative vision of education, we need to adopt a historical and contextualised approach, avoiding technological determinism and uninformed advocacy for a shift from anachronistic, 'analogue' pedagogy to innovative, 'digital' pedagogy. Depending on how they are designed and used, digital education media and resources may well promote or undermine opportunities for 'learning to learn' and 'learning to think', which serve as essential foundations of our capacity for innovation as well as our ethical discernment and sense of responsibility that are needed to harness machines to shape a peaceful and sustainable society.

Key Message 1: The key role of textbooks in a digital era is to offer structure for core content and act as an organizer of a pool of abundant external resources

The 'digital divide' within and across countries continues to be a major form of exclusion and poses challenges to equity and social justice. We nonetheless moved from a situation where educational resources were scarce to a situation of abundance, a phenomenon that has accelerated with the deployment of the Internet. Although the context of abundance is far from universal and paper textbooks often continue to play a central role in low-resource and weak infrastructure settings, the issue of resource selection has become crucial in the current environment. Textbooks and digital textbooks can be of key importance because they have several essential characteristics: most, if not all, textbooks are based on systematized subject-matter and pedagogical knowledge, aligned with the organization of the school system, and thus can be implemented easily by teachers. Today textbooks can be enriched or augmented, they can offer links to external resources, integrate teachers' personal resources, provide different paths and facilitate differentiated pedagogy. In an era characterized by a shift from closed-ness to openness and selection, a key role of textbooks — a hybrid of digital and paper — can be to offer structure for core content and to act as an organizer of a pool of external resources.

Key Message 2: Digital education media and resources have the potential to open up new pedagogical possibilities

The figure on following page presents a heuristic model to illustrate pedagogical opportunities opened up by digital technology — conceptualized as 'affordances', enabling new learning and assessment opportunities and experiences.



Digital technology can be used either for surveillance or collective intelligence, for indoctrination or fostering critical thinking. As underlined in the following message, it is up to human beings, through the organizations and institutions we create, to steer digital learning towards advancing desirable pedagogical and social outcomes.

Key Message 3: Implementation of digital education requires consideration of those actors who use digital education resources (both educators and learners) and the context in which they are used.

Pedagogy is often hypothesized as embedded in educational software design, and practice as the unproblematic application of theory. In most cases, however, implementation is not as simple as applying what has been proven to 'work' in one context to another context. Successful implementation requires contexualization, capacity development of teachers and providing additional support to learners from less privileged backgrounds. The use of digital resources can contribute to achieving equity in and through education, if we are to beware of possible drawbacks and set up adapted environments for 'at risk' population. Simply shifting from face-to-face to online learning will likely leave socio-economically disadvantaged populations behind.

Reflections on the future of technology in education

The three timelines in this report give interesting elements for reflecting on the role of technology in education. **Timeline 1** shows the book as a technology and the explosion of information and communication technologies in the 19th century, with each technology developing independently from one another. During the 20th century, as **Timeline 2** illustrates, these technologies were complementary to books in education, with the gradual rise of (digital) computing. **Timeline 3** shows the double movement of the emergence of large digital platforms. On the positive side, this is associated with an open education movement; on the negative side, this is linked to issues of privacy and data protection. Today we are simultaneously witnessing the unprecedented possibilities for openness and participation on one hand and for the reinforcement of control and surveillance on the other.

Key recommendations

Recommendation 1:
Develop digital textbooks and digital education media that meet the needs of educators and learners

- Provide accessible and easily readable digital resources by students (and parents)
- Ensure selection of resources in a variety of media, keeping the process of selection transparent and flexible
- Facilitate the inclusion of new resources (from teachers, students, and others) to meet appropriate student and subject needs
- Ensure an enabling environment in schools: providing appropriate support to the management of educational resources (licensing and copyright issues; devices; infrastructure; access to the Internet)

Recommendation 2:
Optimize the affordances of digital education media and resources for learner engagement and outcomes

- Use technology to enhance active and meaningful engagement in learning.
- Align pedagogical approaches to a clear vision of the evolving purposes of education. As articulated in SDG 4, this purpose includes but goes well beyond instrumental career readiness and therefore requires pedagogies that support development of a whole person.
- Transform the ends and processes of assessment as a fulcrum for pedagogical reform.

Recommendation 3:
Ensure that teachers keep digital educational resources alive for the benefit of students

- Ensure availability of pre- and in-service teacher training concerning creation or modification of resources: mixing teacher training and creation of scenarios and co-design with teachers.
- Identify, trial, and improve scalable capacity building measures for integrating subject specific teacher resource development with the aspirations of sustainable development.
- Engage with and shape adaptive and customizable dashboards of learning data.
- Build teacher capacities to understand and address equity issues in learning with technology.
- Facilitate the formation of collective identity and responsibility of teachers through empowered agency at the local, regional, and global level. Examine ways to help teachers to organize collectively.

CHAPTER 1

Context, Purpose and Scope of the Global Review

Ongoing societal changes pose complex challenges for education. Digital technologies, which have profoundly changed many human activities, hold one of the keys to addressing them. Technology cannot transform education overnight by their own magic alone. However, people and organizations can promote, support and regulate its use in various education systems and learning environments — and this report is intended for these actors. The primary objective of the report is to provide useful information and insights to understanding digital technologies, their educational potential and the problems involved in their implementation in diverse contexts, based on a review of the wide range of appropriate research literature.

This introductory chapter aims to establish a conceptual framework to structure the reading of the report. It presents the issues underlying the use of digital technology in education, helps decipher the ongoing debates, and describes the different possible roles of digital technologies in education and their implications for teaching and learning. The chapter concludes by presenting the structure of the report and outlining the chapters to follow, which together portray an organized 'state of the art' of digital education resources, informed by history and contrasting examples of their implementation in different settings.

1. Introduction

The challenges we face today are very different from those faced in the last millennium. While experiencing unprecedented interconnectivity created by the Internet, we are also witnessing alarming trends of an overload of information and the misuse of private information, along with proliferation of false news and online disinformation. Also on the rise are new and renewed disparities and tensions, often fuelled by illiberal and undemocratic trends, and uncertainties and risks about the future of the planet we share. Interconnected local to global challenges — ranging from localized violent extremism to climate change — call for education that enables learners to engage creatively and responsibly with the rapidly changing world.

With the exponential growth of digitally mediated communication, digital media and gaming, the landscape of what we understand as learning environments is changing significantly. The growing power of digital giants and their digital platforms (Google, Amazon, Facebook, Apple, Microsoft) is becoming a force that cannot be ignored in discussion of the futures of education. How will States ensure that the use of digital technology in education contribute to promoting inclusive and equitable quality education and enhancing lifelong learning opportunities for all, as articulated in the Sustainable Development Goal (SDG) 4 (see **Box 1-1**)? And what would be the roles of other major stakeholders in education, including educators, educational technology (EdTech) companies, and publishers, in achieving this ambitious goal?

Box 1-1 SDG 4 and Target 4.7

In September 2015, a new global agenda toward pursuing a sustainable future for all was unanimously adopted by the 193 Member States of the United Nations. The resolution adopted is titled Transforming Our World: The 2030 Agenda for Sustainable Development (A/RES/70/1), and includes 17 Sustainable Development Goals (SDGs).

The SDGs embody a shared international aspiration and intergovernmental commitment to meet a range of targets by 2030. The United Nations Educational, Scientific and Cultural Organization (UNESCO), as the global coordinator of SDG 4, is committed to realizing the SDGs through improvement of the quality of education worldwide, by seeking to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (UN 2015).

SDG 4 has seven targets (4.1 to 4.7) and three implementation strategies focused on learning environments (4a), scholarships (4b) and teachers (4c). Whereas SDG Targets 4.1 to 4.6 focus mainly on expanding educational opportunities and equipping learners with skills for employment, Target 4.7 rearticulates a humanistic agenda for education and underscores the international consensus on promoting transformative education to advance well-being for all:

> *"By 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development." (UN 2015)*

UNESCO promotes Education for Sustainable Development (ESD)[1] and Global Citizenship Education (GCED)[2] as two pillars of SDG 4.7. Although the definitions of ESD and GCED have been debated, UNESCO defines them broadly as education that equips learners with knowledge, skills, values and dispositions that allow them to contribute to shaping more peaceful and sustainable societies.

Today the use of digital technology in education is attracting considerable public and policy attention as well as private investment. In recent years governments around the world have been looking into technology integration as a means of educational change, irrespective of the level of economic and educational development. For example, in 2013, the Kenyan government launched the Digital Literacy Programme (see **Box 5-11**), and in 2016 the Hungarian government launched the Digital Success Programme, including the Hungarian Digital Education Strategy (see **Box 3-4**). In late 2017, Singapore introduced the Student Learning Space — an online learning platform that contains curriculum-aligned resources and learning tools — which contributes to the country's Smart Nation strategy. The Strategy states: "Digital technology unlocks a new realm of self-directed and collaborative learning. Relationships between students, teachers and parents, as well as capabilities of the physical infrastructure are augmented to create a holistic and conducive environment for effective learning" (Singapore 2018, p. 7).

Although each country's context and challenges are unique in such efforts, they often espouse common goals, namely,

1. **Address the issue of educational access and equalize access to (quality) educational resources**
2. **Improve learning outcomes by implementing learner-centred approaches with the support of digital platforms and resources**
3. **Redesign or reengineer conventional education models.**

Those who promote a greater use of digital technology in education have imagined schools where students acquire '21st century skills' in a personalized and collaborative way and at their own pace, with teachers taking on the role of facilitators of learning. At the same time, technology tracks student progress and digital platforms connect learners to peers, mentors and experts — both real and virtual — all around the world and a broad array of digital resources. Today's advocates of 'digital education' — digital learning, digital pedagogies, digital resources, digital classrooms, digital schools — seem to be convinced of the promises of the digital technology in 'revolutionizing', or 'disrupting', ineffective education models.

It is however important to be fully aware that these technologies have also raised serious concerns with profound social and ethical implications. For example, the Republic of Korea announced its intention of going fully digital in school education, but in spite of a well-planned schedule put

1 "ESD empowers learners to take informed decisions and responsible actions for environmental integrity, economic viability and a just society, for present and future generations, while respecting cultural diversity. It is about lifelong learning, and is an integral part of quality education. ESD is holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment. It achieves its purpose by transforming society" (UNESCO 2014a, p.12).

2 GCED addresses three core dimensions: "Cognitive: To acquire knowledge, understanding and critical thinking about global, regional, national and local issues and the interconnectedness and interdependency of different countries and populations; Socio-emotional: To have a sense of belonging to a common humanity, sharing values and responsibilities, empathy, solidarity and respect for differences and diversity; Behavioural: To act effectively and responsibly at local, national and global levels for a more peaceful and sustainable world" (UNESCO 2014d, p.15).

forward in the 1990s, Korea held back its plan to roll out the fully digital learning environment. Reasons for postponing the plan included the harmful effects of students' overexposure to digital devices (Harlan 2012, as cited by Smart and Jagannathan 2018, p.59). Indeed, concerns with the penetration of digital technology in every sphere of our lives are varied, "ranging from online safety and security (identity theft, scams, system phishing, hacking, online predators and cyber bullying) to misuse of information (plagiarism, access to inappropriate content, and misrepresentation) to health and mental hazard (long exposure to screen, back and arm pains, and game/internet addiction)" (UNESCO Bangkok 2015, p.1), as well as new challenges for information self-determination, the secure handling of data, and the traceability of both online and real-world action that may be contrary to privacy principles (Isin and Ruppert 2015).

With a rise in discourses both heralding and cautioning against the use of digital technology in education, there is a need to pool the expertise and experience on the use of technology in education from around the world to advance public debate and evidence-informed policymaking.

Furthermore, Vorvoreanu (2014) points out that, based on insights from cognitive neuroscience, our lifestyle saturated with digital technology may lead to attention disorders, which have serious implications for education. Attention regulation is critical to attaining and sustaining deep focus and the state of "flow" as articulated by Mihaly Csikszentmihalyi (1991, 1997), which in turn have deep and direct connections to active learning. As Bell (2017) observes, the concept of "flow" has often been cited in the literature on games and gamification. While the kind of immersive learning enabled by digital technologies holds promise for the futures of education, the same technologies may lead to the difficulty in focusing attention and the diminishment of our cognitive capacities — and life satisfaction.

With a rise in discourses both heralding and cautioning against the use of digital technology in education, there is a need to pool the expertise and experience on the use of technology in education from around the world to advance public debate and evidence-informed policymaking. Based on the literature review, mapping of digital education resources in circulation, and examples of implementation of digital education initiatives from around the world, this report aims to provide insights that would help lead to the *wise*, *innovative* and *ethical* use of digital technology in education as a new dimension in achieving the SDG 4. By so doing, it also attempts to contribute to a rethink of teaching and learning in the face of enormous opportunities and challenges brought about by digital technology in the times of change and turmoil.

Focus on digital education resources

This report focuses not only on properties or technological features of digital learning resources and digital media, but also on how they have evolved over time, and how they are conceptualized, designed, developed, distributed, implemented and used. The focus on digital education resources is critical because textbooks and other education materials are important strategic areas of intervention for improving the quality of education, along with other key inputs into formal education such as curriculum and teacher education. As a recent report on textbook policies by the Asian Development Bank argues:

> *"Textbooks provide an axis for coordinating input to improved learning outcomes. They reach all corners of a country and find their way into schools and into the hands of teachers, principals, students, and parents. Textbooks can also guide other critical inputs in education such as pre-service teacher education and in-service teacher training, school supervision, and student assessment" (Smart and Jagannathan 2018, p.x).*

Although the importance of school textbooks is still largely unchallenged especially in centralized education systems, with the rise of a wide range of digital education resources, the traditional place of the textbook in education is changing. This review will therefore address the following key questions.

- How has the notion of textbooks evolved over time (Chapter 2)?
- What kinds of digital education resources are in circulation today (Chapter 3)?
- How do the definition and role of textbooks change in the digital era (Chapter 3)?
- How can digital technology facilitate teaching and learning (Chapter 4)?
- What are the challenges of implementing digital education initiatives (Chapter 5)?

In exploring these questions, we are fully cognizant that educational resources alone — whether paper or digital or hybrid — are not sufficient to achieve equitable quality education. A recent study by Harvard University, for example, showed no evidence of differences in achievement growth for schools using different elementary mathematics textbooks in six states in the United States, but it suggested that textbooks might make a difference if greater support is provided for classroom implementation (Blazar et al. 2019).

Advocates of digital education have hoped that digital resources would be less dependent on teacher quality and other factors and therefore could contribute to closing gaps in access and achievement. However, research increasingly shows that simply going digital does not lead to more equitable outcomes. For example, a recent report titled "Promises and Pitfalls of Online Education", published in the Brookings Institution's Evidence Speaks series, shows that socio-economically disadvantaged students' learning and persistence outcomes are worse when they take online courses than face-to-face courses (Bettinger and Loeb 2017).

This points towards the need to address what sociologist Paul Attewell (2001) called "the first and second digital divides" — the first about *access* to technology (e.g. hardware, software, connectivity) and the second about its *usage*. Privileged learners are more likely not only to (i) have opportunities to use digital tools but also to (ii) use technology for more creative purposes (as opposed to drill and practice) with more adult support. We need to rethink digital education resources not merely as digital education media or delivery vehicles for instruction but as pedagogical tools that take into account how people learn with technology. There is much room to improve the design and use of digital education resources, by taking into consideration both (i) physical barriers to accessibility to technology and (ii) social, cultural and psychological barriers to learning with technology.

We need to rethink digital education resources not merely as digital education media or delivery vehicles for instruction but as pedagogical tools that take into account how people learn with technology.

2. Calls for a Paradigm Shift in the Model of Education

In our time when 'sustainable development' has emerged as a universal agenda for both developed and developing countries, there is an international consensus — affirmed in various declarations and frameworks — that reorienting the purpose of education towards sustainable development is an integral element of quality education (UN 1992; UNESCO 2005a, 2014a, 2014b, 2016, 2019a). Increasingly such calls are underpinned and reinforced by the need to achieve a paradigm shift

in education— transformative shifts in educational practices, institutions, and policies required for understanding and enhancing individual and collective human well-being in profoundly different ways.

The recent UNESCO report ***Rethinking Education: Towards a Global Common Good?*** highlighted the importance of learning to live together on a planet under pressure by calling for the principle of education as a 'global common good' (UNESCO 2015a). Rethinking education as a global common good is even more relevant today, with new possibilities and potential threats brought about by digital technology. At a time when the entire content of K-12 textbooks can fit in a USB flash drive and the Internet seems to put the whole world at our fingertips, the central issue is a call for "learning to learn" and "learning to think" in the 21st century.

However, this call for "learning to learn" and "learning to think" needs to be understood against the backdrop of standards-based education reforms across the early 21st-century world, involving the adoption of standardized testing. The emphasis is often on improving individual student performance measured against a set of metrics, which may be at odds with important educational goals such as fostering engaged citizenship and valuing diversity. Depending on how it is designed and used, digital technology in education may well promote or undermine opportunities for "learning to learn" and "learning to think", which serve as essential foundations of our capacity for innovation as well as our ethical discernment and sense of responsibility that are needed to harness machines to shape a peaceful and sustainable society.

Not only has technological advancement enabled new ways of presenting, archiving and interacting with content, it has also allowed new ways of creating and sharing content. In considering the role of digital technology in the inclusive and sustainable development agenda, there is a need to explore what digital technology *affords* — makes possible and supports — in terms not only of making learning effective but also of co-creating and sharing knowledge. The notion of "affordance", which will be discussed in Chapter 4, simply refers to possibilities offered by digital technology.[3] It indicates that technology makes it *logistically* easier to implement some of pedagogical forms.

In considering the role of digital technology in the inclusive and sustainable development agenda, there is a need to explore what digital technology affords — makes possible and supports — in terms not only of making learning effective but also of co-creating and sharing knowledge.

Digital technology provides new types of media that can facilitate problem-based and project-based approaches and foster collaborative learning. It is also important to consider the 'open education' affordances of digital technology — the possibilities to broaden access to and participation in learning for all.[4] Scholarly and policy work on open education has focused mainly on higher education with discussions around Open Education Resources (OERs) and Massive Open Online Courses or MOOCs (Conole and Brown 2018). Reflection on open education affordances and limitations in the context of compulsory education is still at a nascent stage. In this report, examples from Mexico (**Box 3-2**), Brazil (**Box 3-6**), India (**Box 4-6**), the Pacific islands (**Box 5-10**), and Kenya and Uganda (**Box 5-11**) shed some light on the potentials and limitations of using OERs for school education.

3 The notion of 'affordance' has been widely used in the literature on learning with technology to describe the properties of technologies. As Martin Oliver (2005) pointed out, however, the concept tends to be far removed from its origins. The concept of affordances as used in this report has no connection to how it was originally used to describe animal-object relationships by James J. Gibson, which in turn appropriated by Donald Norman to describe actions users consider possible (or perceivable action possibilities) in human-computer interaction.

4 In the OpenEdu project of the European Commission, open education is defined as "a way of carrying out education, often using digital technologies. Its aim is to widen access and participation to everyone by removing barriers and making learning accessible, abundant, and customisable for all. It offers multiple ways of teaching and learning, building and sharing knowledge. It also provides a variety of access routes to formal and non-formal education, and connects the two" (Inamorato dos Santos et al. 2016, p.10).

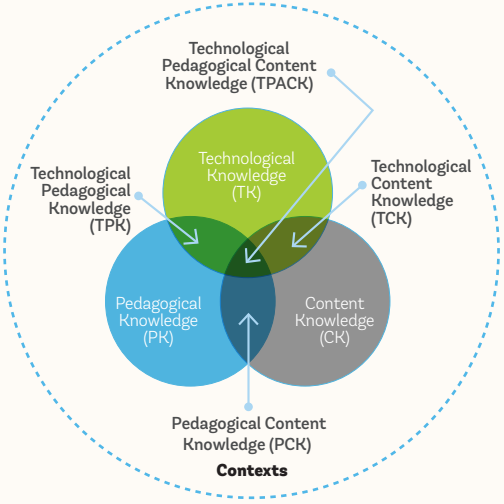
At the intersection of calls for 'paradigm shifts' in the model of social progress and that of education is the notion of 'transformative learning' — the kind of learning that enables learners to go beyond the status quo and transform societies for the better. The current review considers forms of pedagogy which are appropriate to the digital era and can support the aspirations of sustainable development in its broadest sense of the word — going beyond economic viability and ecological integrity and addressing the principles of "leaving no one behind" and "life of dignity for all" (UN 2015). In undertaking the global review of digital education resources, we will therefore pay attention to the wider societal implications for promoting digital solutions to educational problems.

3. The Roles of Digital Technology in Education

How can digital technology and its use contribute to active pedagogy to equip learners with knowledge and skills required for sustainable development? This includes acquisition of foundational skills of literacy and numeracy as well as fostering of competencies to engage with the world more creatively and responsibly. Koehler, Mishra and Cain's (2013) TPACK (Technological, Pedagogical and Content Knowledge) framework is one introductory way of considering this question. The TPACK framework builds on Shulman's (1986, 1987) 'pedagogical content knowledge (PCK)' construct to describe how teachers' understanding of technology interacts with PCK to produce effective teaching with technology. More concretely, the TPACK framework underscores the importance for teachers to develop

> *"an understanding of the representation of concepts using technologies, pedagogical techniques that use technologies in constructive ways to teach content, knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face, knowledge of students' prior knowledge and theories of epistemology, and knowledge of how technologies can be used to build on existing knowledge to develop new epistemologies or strengthen old ones" (Koehler, Mishra and Cain 2013, p.16).*

Figure 1-1 TPACK Framework (Koehler, Mishra and Cain 2013)



The TPACK framework has the teaching of disciplines or subject areas with clear progressions in mind. As the current review focuses not only on subject-based teaching but also on the use of technology not directly linked to a specific subject, in both formal and informal settings, it is useful to clarify different practices associated with the use of technology in education, in order to better understand the scope of the current literature review. We will mainly look at digital technology as (1) an educational technology, (2) an instrument at the heart of the disciplines taught, (3) ICTs for organization, communication and investigation of tasks in the classroom and at home, and (4) a new subject area to teach knowledge and skills needed to create digital solutions to emerging and persistent challenges of our society (e.g., computational thinking, coding and programming skills) (see **Box 1-2**).

Box 1-2 Four main roles of digital and associated technologies in education

1. **Digital technology as an educational technology**
   Digital learning can mean using digital technology as a means of teaching and learning, that is, as an educational technology. It is a question of learning and teaching differently what is already being taught. Educational technologies include any tool or equipment, not necessarily digital, used for educational purposes such as paper textbooks, blackboards, television and radio. Digital versions of these are e-textbooks, electronic whiteboards, streamed video and podcasts.

2. **Digital technology as an instrument at the heart of the disciplines taught**
   Each discipline has its own instruments that are renewed with digital technology: soundscapes in music, geographical information systems in geography, computer-assisted experimentation in experimental sciences, dynamic geometry in mathematics, recording of heartbeats in physical education and sports, and so on.

3. **Digital technology as ICTs**
   This role is about the use of digital technology as ICTs for organization, communication and investigation of tasks in the classroom and at home, regardless of what is being taught. It facilitates access to documents; development and modification of written, audio, audio-visual materials; and so on. This implies the acquisition by learners of skills or, more broadly, of a culture of using these technologies safely, effectively and responsively. UNESCO ICT Competency Framework for Teachers (UNESCO 2008a, 2011, 2018a) underscores the importance for teachers to foster students' skills to collaborate, solve problems and become creative in the use of digital technologies. This is in addition to themselves being equipped to manage digital technologies and teach them to their students.[5] In our digital age, these skills become part of citizenship training to participate fully in society.

4. **Digital technology as a discipline or a new subject area**
   Digital technology as a new subject area can include developing knowledge and understandings of the underlying concepts of information systems, data and computer science, and skills to master digital systems such as coding or programming and, more broadly, computational thinking.

5 There have been three versions of the ICT CFT: 2008, 2011 and 2018. The 2008 original version was developed in partnership with CISCO, INTEL, ISTE, Microsoft and subject-matter experts.

These four faces of digital technology require a corresponding set of changes in competences of educators to respond to the increased use of digital technology in education, as briefly outlined below. The first three types of competences correspond to the three main components of the TPACK framework (Koehler, Mishra and Cain 2013; see **Figure 1**).

1. **Technical changes** refer to changes in the required technical competence of teachers, such as knowledge and skills to use digital devices (e.g., computer, whiteboard and tablet as instruments).
2. **Instructional changes** refer to changes in subject-based teaching competence. They include changes in knowledge and skills that affect the quality of teaching within the subject area, such as being able to choose and use an appropriate computer simulation to enhance student understanding of the subject matter. This corresponds to 'content knowledge' (including technological content knowledge' and 'pedagogical content knowledge') in the TPACK framework. To refer to this dimension, the word 'didactics' is commonly used in countries in the European continent[6]
3. **Pedagogical changes** refer to changes in pedagogy that transcend subject boundaries. This corresponds to 'pedagogical knowledge'[7] in the TPACK framework: "teachers' deep knowledge about the processes and practices or methods of teaching and learning" (Koehler, Mishra and Cain 2013, p.15). The increased use of digital technology—inside and outside of classrooms—has implications on appropriate modes of intervention in the classroom and practical management of teaching-learning activities.
4. **Epistemological changes** refer to changes in the very objects of teaching and learning. The increased use of digital technology—in education and in society—calls for rethinking of the underlying systemic aims of education. In considering how digital technology can support SDGs, it is important that pedagogical changes be guided by a deep understanding of what it means to learn to live together in an interconnected and interdependent world and on a planet under pressure.

In Education 2030 Framework for Action for the Implementation of SDG 4 (UNESCO 2016), ICTs are mentioned mainly in relation to non-formal and informal learning settings. Although it is stated that ICTs "must be harnessed to strengthen education systems" (ibid, p.8, paragraph 10), exactly how they should be deployed to support formal schooling is left largely unaddressed. In 2018, UNESCO published guidelines for designing inclusive digital solutions and developing digital skills, targeting low-literate and low-skilled people, with particular reference to SDG Target 4.6 on literacy and numeracy and SDG 8 on decent work for all (UNESCO 2018b). These guidelines address mostly non-formal and informal learning. Articulation of the role of digital technology in re-envisioning formal education and learning environments more broadly is still insufficient.

In addition to the complexity involved in the use of digital technology in education discussed above, the term 'digital learning' also has multiple meanings. For some, digital learning means digitally-mediated learning that provides learners with some control in terms of pace, content, time, place and/or path. For others, digital learning means learning of 'digital skills', 'digital competencies', or

6 As Andrews (2007) points out, the word 'didactics' is not in common usage in the English language and the adjective "didactic" is often used in a pejorative sense in English, signalling an intention "to teach, especially in a way that is too determined or eager, and often fixed and unwilling to change" (Cambridge Dictionary) or "to teach or give moral instruction" (Oxford Dictionary).

7 This includes 'technological pedagogical knowledge', which is understanding of "the pedagogical affordances and constraints of a range of technological tools as they relate to disciplinarily and developmentally appropriate pedagogical designs and strategies" (Koehler, Mishra and Cain 2013, p.16).

'digital literacy'.[8] There is much debate on how to define 'digital skills', but they can be broadly defined as "skills and competencies needed to make use of digital technology and benefit from its growing power and functionality", and be "best understood as existing on a graduated continuum from basic functional skills to higher level, specialist skills" (Broadband Commission on Sustainable Development 2017, p.4). For example, some argue that learning in a digitalized world necessitates learning about digital media (Buckingham 2006), or understanding the basis of digital systems (Engagement Global 2018). Given that digital technologies underpin effective participation in key areas of life and work, the definition of digital skills is being expanded to include digital citizenship. For example, digital citizenship can include the capacity for safely making the digital rights claims that are necessary for modern global digital citizenship within the realities of various local contexts (Isin and Ruppert 2015), or citizenship skills and attitudes that allow digitalization to be effectively leveraged for sustainable development and that also meet the full range of challenges that digitalization poses (Gómez-Zermeño 2012).

'Digital learning' has multiple meanings: digitally mediated learning, learning of 'digital skills'. 'digital competencies', or 'digital literacy'

4. Structure of the Report

With countries around the world announcing their intention of rendering the learning environment in schools fully or partially digital, it is timely to explore the potentials and limitations of digital technologies in supporting equitable quality education. The current report draws on a body of knowledge about the role of technology in education (review of academic and policy literature), the mapping of existing digital textbooks and other digital education media and resources (review of existing digital resources), and examples of the implementation of digital education initiatives from different continents. More specifically, the report will:

1. Provide a rationale of the global review of digital education resources
2. Provide an overview of the development of textbooks and educational resources from a historical perspective
3. Describe and critically assess existing models of digital education resources, including digital textbooks and associated initiatives, in terms of their design and intended use
4. Discuss pedagogy enabled or facilitated by digital technology, and present a model that helps explore the pedagogical possibilities of digital education resources
5. Draw lessons from examples of design, implementation and use of digital textbooks and associated initiatives from across the world
6. Provide recommendations for decision makers.

This chapter has positioned the review exercise in relation to the context of SDGs and to the role of technology in improving education. Chapter 2 tracks back into history in order to develop a better understanding of the current situation with regard to digital textbooks and learning resources. Taking up George Santayana's famous aphorism "Those who cannot remember the past are condemned

8 'Digital literacy' comes under SDG Target 4.4, which focuses on "relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship" among youth and adults. To address the need to collect data for the SDG 4 indicator 4.4.2, "Percentage of youth/adults who have achieved at least a minimum level of proficiency in digital literacy skills", a task force of experts and country representatives established by the Global Alliance to Monitor Learning (GAML) defined digital literacy as "the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital devices and networked technologies for participation in economic and social life", including "competencies that are variously referred to as computer literacy, ICT literacy, information literacy, and media literacy." The task force proposed seven competence areas of digital literacy: fundamentals of hardware and software; information and data literacy; communication and collaboration (through digital technologies); digital content creation; safety; problem solving; and career-related competences. See http://uis.unesco.org/en/blog/global-framework-measure-digital-literacy and UNESCO (2019b, p.19).

to repeat it", the chapter traces the historical development of books, textbooks and schoolbooks mainly in the European context. Textbooks, whether paper or digital, are not only technical tools; they are also cultural and ideological artefacts. They explicitly convey a historical understanding and a worldview as well as conveying norms and values. Chapter 2 makes connections between the current forms of textbooks and their historical antecedents.

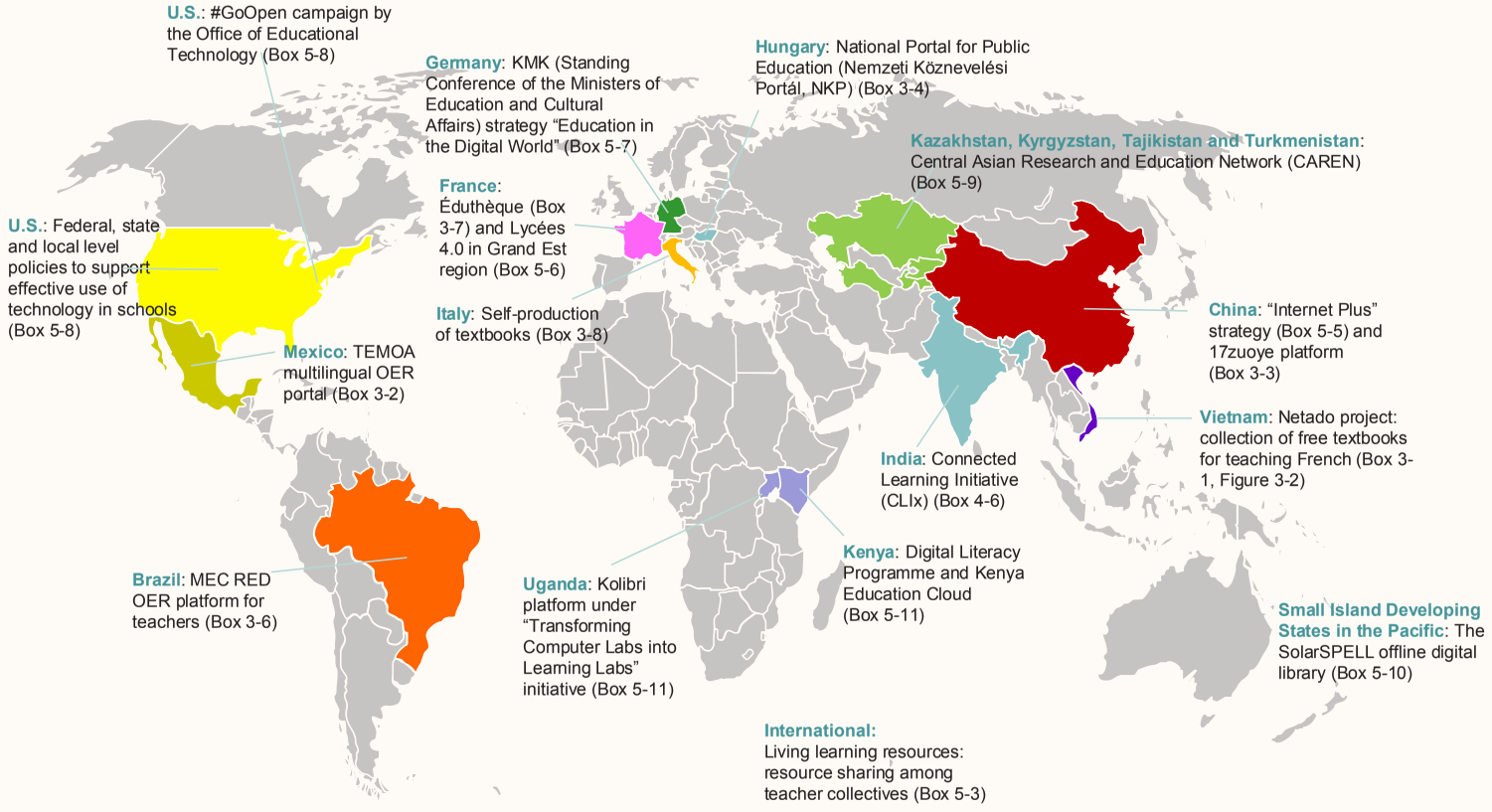
Chapter 3 provides the current definition and design of digital textbooks and other digital educational media and resources. It presents and categorizes a set of recent digital educational resources from different continents and highlights some of their characteristics. It introduces a possible new role for textbooks as well as new design processes involving local actors.

Subsequent to the study of digital products in circulation, Chapter 4 focuses on the pedagogies they can support. To explore the pedagogical possibilities of digital resources, it puts into perspective the visions and theories of learning underpinning what is often uncritically espoused as 'learning solutions' and 'learning innovations'. It then presents the '8 Affordances' or the 8A model, which is newly developed for this review based on the 'e-learning ecologies' or '7 affordances of the digital' model of Bill Cope and Mary Kalantzis (Kalantzis and Cope 2015; Cope and Kalantzis 2017) as well as several other models. The chapter explores how the 'affordances' of digital technologies open up pedagogical possibilities that can support SDG 4.

Chapter 5 draws on several case studies to present how these products and pedagogies are being implemented in real-life settings in different continents. It focuses on actual uses and what concretely makes these uses possible, and attempts an analysis of the interactions between systems (educational systems at different levels, publishing sector, infrastructure, curricula), instruments (digital products) and actors. This raises policy and implementation implications. Concerning the instruments or products, the chapter looks at only one example, Minecraft, a game that has been very successful. It explores the purpose for which it is used in education, and also how it can be used in different ways. Regarding the actors, the focus is on teachers, not as individuals, but as a collective actor. On the systems side, the chapter presents several case studies: examples of implementation of digital technologies in European countries (Hungary, Germany and France), and also in the United States, China, Central Asia, Small Island Developing States (SIDS) in the Pacific, and in Africa. These case studies help us better understand nuanced differences and factors involved in implementation.

Based on the analyses conducted in the preceding chapters, the final chapter makes policy recommendations for the development of digital textbooks and supplementary materials, and more generally, on the use of digital technologies in education, highlighting the role of different actors, including teachers' collectives.

Figure 1-2 Examples of implementation of digital education initiatives included in the report



CHAPTER 2

From Books and Textbooks to Digital Educational Media: Historical and Conceptual Landmarks

The chapter provides an overview of historical developments in educational resources, particularly with regard to digitization. A passage through history, both of schoolbooks and associated tools, but also of the very notion of books, should enable us to see more clearly the different dimensions of digital objects—more or less close to what we know as books, notebooks (exercises carried out by students), and boards (collective writing and reading)—that may be involved in education.

The reader in a hurry may consult this chapter quickly to go to the next chapter presenting the current offers of digital textbooks and digital education resources. However, in order to understand the present situation, it is important to appreciate how digital textbooks are in continuity with paper textbooks. The latter has an ancient history, associated with the history of the book. Textbooks have very recently incorporated elements from the teaching machines of the 20th century and computer developments of the 1970s and beyond. It is also critical to understand that, when it comes to educational resources, it is not only a question of technology, but also of ideology and history. This understanding is reflected in the structure of this chapter.

1. Historical and Conceptual Landmarks of Paper Textbooks

Without doubt, books have been a key tool of formal education. With digital technology, the notion of what a book can be is evolving and, therefore, notions of the textbook are evolving as well. There is a tendency among some to oppose both paper-based and digital textbooks, but this overlooks the fact that textbooks have a history and that technologies have changed paper textbooks significantly over the past century. Technological developments and changes in teaching and learning models interact with one another. New digital textbooks inherit these developments, and are also opening up new possibilities.

Box 2-1 Textbooks and schoolbooks

According to Sammler (2018), textbooks "became the central medium of national education, which was carried out through institutionalised national education systems starting in the nineteenth century". But the term textbook is neither precise nor stable (Johnsen 1993, chap. I): the definition of a textbook is so general that it may include other books produced and published for educational purposes, or even any book used in the classroom. Johnsen proposed distinguishing textbooks, designed for education, from schoolbooks, used in education. Choppin (2008) pointed out that, since the 1970s, another, more pragmatic but equally unstable and contested, distinction has prevailed in the educational research community between textbooks and teaching media.

According to Choppin (1992), schoolbooks can be classified into four main categories: (1) materials "designed with the intention, more or less explicit or manifest ... to serve as a written medium for the teaching of a subject within a school institution", (2) classical editions (classical works reproduced in whole or in part) "abundantly annotated or commented for use by classes", (3) reference tools (e.g., dictionaries, atlases, précis, mementos, document collections), and (4) extracurricular books.

This chapter begins with some references to the history of textbooks and schoolbooks, the latter characterized by Choppin (2008) as a falsely obvious historic fact. Then it touches upon the transition from paper books to electronic books (e-books), which leads to some historical references on teaching machines up to the current Internet platforms. The next chapter introduces the concepts of digital textbooks and digital educational resources.

1.1 Textbooks and schoolbooks: Some landmarks

Before tracing the history of books, one needs to understand why books originated in the first place. Historians, for years, have been debating when writing systems and education systems began. According to historical discoveries made so far, Mesopotamian civilization is considered to be the oldest civilization to use written texts in learning.

The archaeological context outlined in **Box 2.2** points to the intriguing connection between the development of writing and scripts and the history of the media of knowledge transmission that predated books. In this context, the textbook in its present form has a quite recent origin. It represents only a subset of the broader category of 'schoolbook'— a category so varied that it defies any classification attempt (Choppin 2008; see also **Box 2.1**). According to this wider meaning, the origin of the schoolbook dates back to the ancient Babylonian culture. The Greeks, and then the Romans, also used schoolbooks; they were also used during the medieval age. Parallel changes were occurring in ancient Chinese and Indian traditions of writing.

A long time before the invention of the printing press, schoolbooks were manuscripts designed to facilitate the acquisition of concepts and memorization, with a more or less explicit teaching intent. Among the first books printed in Magonza (the modern city of Mainz in Germany, where Johannes Gutenberg started the Printing Revolution in 1439), other than the Bible, was the *Ars minor* by the 4th century Roman grammarian Elio Donato, one of the most famous preparatory texts for learning Latin in the Middle Ages. From that moment, 'study books' became a specific genre with a naturally wide audience, and therefore became immediately attractive to both writers and to the nascent publishing industry.

Box 2-2 Media of knowledge transmission and ancient learning traditions (by Arnab Mandal, Mary Kalantzis and Bill Cope)

The earliest surviving papyrus scrolls that contain written words date back to 2400 BC and originated in Egypt. Various historians, however, have suggested that papyrus could have been used as early as 3100 BC.[9] Historical evidence suggests that paper in its present form was invented in China during the Han Dynasty (202 BC to 220 AD)[10]. In the 11th century, paper-making technology came to Europe, and this can be considered as the beginning of a new era of book printing.

As a background to tracing the history of books and textbooks, it is interesting to look into a multi-millennial history of knowledge transmission and the development of media that predate the invention of paper. Writing emerged independently in four different places: Mesopotamia (cuneiform), Indus Valley, ancient China, and Mesoamercia. Egyptian hieroglyphs (3200 BC) and Indus scripts (a3500 BC) were used for writing lexicologically sensible paragraphs on stone and metal.

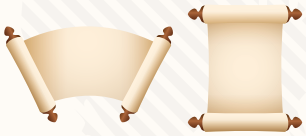
Before modern times, learning was focused on sacred texts, which were not designed as specifically pedagogical artefacts. Learning was by apprenticeship in writing and others areas of knowledge, and the medium was primarily person-to-person oral dialectic epitomized in the Socratic dialogue. For example, archaeological evidence suggests that Rigveda (which consists of 1028 Sanskrit hymns), from the Indian subcontinent, is amongst the oldest scriptures of human civilization[11], and the Vedic education system (approx. 1500 BC) is one of the earliest education systems in the world[12]. For generations, the teaching of the 'vedas' was performed orally. This oral heritage is one reason why the vedas were also called 'shruti' (Sanskrit for 'listening'). Early written forms of the vedas, namely, Rigveda, Samaveda, Yajurvda and Atharvaveda, were written on palm leaves.

In ancient India, Gurukuls were places for young students to reside and attain Brahmavarchasa, the knowledge of the Absolute[13]. The curriculum consisted of the Vedas and Upanishads, Puranas (mythology), history, grammar, mathematics, astronomy, dance, music, physical education and other subjects deemed important by specific teachers. Ancient India also had prominent centres of higher learning or early universities[14] such as Nalanda[15] (UNESCO World Heritage Site), which was a Buddhist Mahavihara (a large monastery) during 400 AD to 1200 AD. Long before the establishment of Al Azhar in Cairo (972 AD), Bologna in Italy (1088 AD) and Oxford in the United Kingdom (1167 AD), Nalanda was a prominent centre of learning[16]. As a consequence of its rich educational offerings, it attracted students from China, Japan, Tibet, Sri Lanka and Southeast Asia[17]. Manuscripts, textbooks and books in general were integral aspects of Nalanda education[18].

9 https://sfbook.com/the-evolution-of-the-book.htm
10 https://www.thoughtco.com/invention-of-paper-195265
11 Sagarika Dutt (2006). *India in a Globalized World*. Manchester University Press. p. 36. ISBN 978-1-84779-607-3
12 http://ncert.nic.in/textbook/pdf/heih111.pdf
13 http://www.tjprc.org/publishpapers/--1466080690-1.%20IJHR%20-Education%20System%20in%20Ancient%20India.pdf
14 https://www.rarebooksocietyofindia.org/book_archive/196174216674_10153420277166675.pdf
15 https://www.bbc.com/news/business-22160989
16 https://nalandauniv.edu.in/about-nalanda/history-and-revival/
17 http://archive.mu.ac.in/myweb_test/ma%20edu/History%20of%20Edu..pdf
18 https://www.aicte-india.org/downloads/ancient.pdf

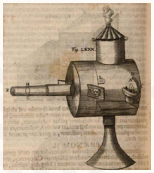
Timeline 1 **History of paper books (book as a technology), from the Middle Ages to the beginning of the 20th century, and main innovations in information and communication technologies**

Invention of paper at least 2 centuries ago
Cai Lun (China)
105 BC



Transition from volumen (or roll) to codex. Definitively acquired in the 5th century (Europe)

Gasparini pergamensis clarissimi oratoris epistolarum liber
First textbook in France
1470



Magic lantern
C. Huygens
1659

Gutenberg Bible
1454

Printing Press
Gutenberg
1440

Movable type printing technology (China)
1040

The codex allow a reader to keep hand free to write therefore annotate, comment and insert the text. It offers a real architecture of the text, sequenced into pages, hierachized into chapters, then into paragraphs, easily flippable thanks to an index.

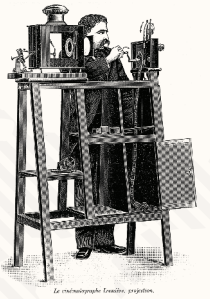
Oldest book printing with movable metal type Jikji (Korea)
1377

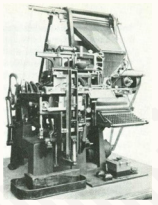
Le codex Gigas
13th century

Sources: « Histoire du livre », BNF. http://classes.bnf.fr/livre/arret/histoire-du-livre/premiers-supports/index.htm
For ICT technologies, see English and French Wikipedia and Wikimedia

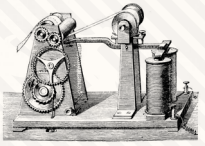
Telephone
Graham Bell
1876

Kinetograph *Edison*
Cinematography *Lumière brothers*
1891





Linotype
Mergenthaler
1884



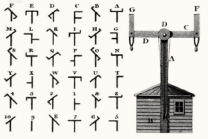
Electrical Telegraph
Morse
1840

Television live
transmission of images
Rignoux & Fournier
1909

Industrial Printing Presses
1800

Photography
N. Nièpce **1822**
Daguerre **1839**

Semaphore telegraph
C. Chappe **1792**



This report includes three timelines. Together they illustrate transitions between worlds that change with the evolution of technologies for knowledge storage and diffusion.

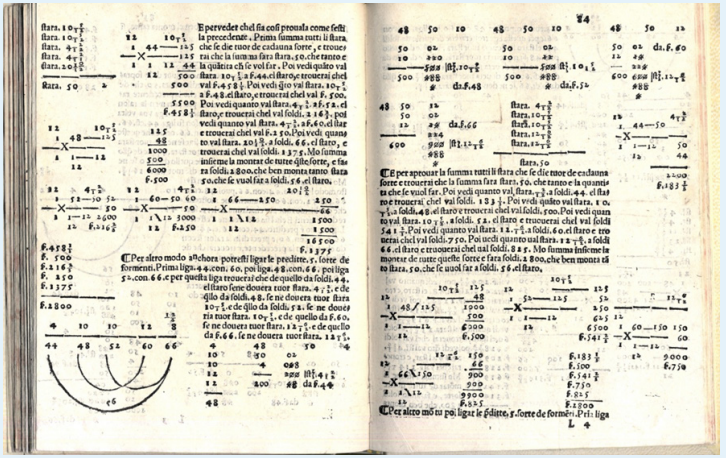
This timeline covers the Middle Ages until the beginning of the 20th century. It shows the evolution of the book, which is the technology of knowledge and its diffusion. It also illustrates the innovations of industrial society during the 19th century. The book is the technology of knowledge in schools.

Note: The sources of images used in the Timelines are listed at the end of the publication.

Although it is considered as a genre of second order, the schoolbook also represents a key tool for the dissemination of knowledge. Its form suggests models, values and principles that are a fundamental part of a learner's training. The 'study book' came to be used widely with the establishment of the popular school, between the 15th and 18th centuries. In France, *Gasparini pergamensis clarissimi oratoris epistolarum liber*, published in 1470, is considered to be the first schoolbook. From those years onwards, pamphlets began to be printed in Europe, ranging from abacus (see **Figure 2-1**) to collections of edifying readings, from science treaties to maths manuals. The *Orbis Pictus* by Comenius, the first picture book for children published in 1658, represents the ideal of education that aims to address everyone. As a work of synthesis and representation, this was a unique moment of innovation in the history of illustrated publishing.

The collaboration between printers and cultural politics came to be strong, well represented in the Grand Duchy of Saxony where, in 1640, the pedagogue Andeas Reyer collaborated with Peter Schmidt (the printer) to produce official schoolbooks for use in local schools. Likewise, in 1776, *the Novelle Morali ad uso de 'Fanciulli* was printed in Milan by Francesco Soave, who was at the time in charge of reforming educational institutions in Lombardy. The years of the Revolution affirmed in France, as in England, the need for an increasingly widespread popular education that required the widespread use of printing presses in the production of resources suitable for study. From that moment on, throughout Europe, schoolbook production became a significant source of income for printers, booksellers and publishers.

Figure 2-1 Pietro Borghi, Libro de abacho, presso Bernardino de Bindoni, Venezia (Book of Abacus, printed by Bernadrino de Bindoni in Venice, Italy), 1540, pp.83-4



Source: The book belongs to the ancient book collection of the library of INDIRE in Florence, Italy, and is in the public domain.

The private purchases of books became more widespread. Owning a textbook meant being able to freely access knowledge, because the book represented the faithful substitute for a master's voice. Indeed, many of the books published were the work of masters, especially of mathematics and the scientific disciplines, but also of humanities. It is no coincidence that, in the second half of the nineteenth century, Pinocchio, arguably the most famous puppet in the world, forced his father to sell his jacket to buy an *Abbecedario,* a book that teaches reading and writing.

With some territorial differences, the textbook continued to evolve in Europe during the 19th and 20th centuries. From the mid-1800s onwards, the political significance attached to textbooks was clear everywhere, especially in vernacular languages for newly established countries, where the nationalistic push was stronger. School textbooks, with elements of national history and geography, became powerful vehicles of identity construction. In the 1930s, the fascist regime in Italy imposed its own version of history and society in a set of textbooks, which demonstrates the political importance of the cultural vision expressed by the schoolbook. After the Second World War, many countries, including Germany, Italy and Japan, worked to 'clean up' textbooks with nationalistic content. In Japan, for example, the post-World War II textbook policy began with a process known as 'suminuri' or 'blacking out' of the militaristic content in textbooks used during the war years (Nozaki 2008, pp. 3-4). In Italy, a Subcommittee on Education of the Allied Military Government (AMG), chaired by Carl Washburne, established the criteria for the revision of schoolbooks in use in elementary and secondary schools in the direction of favouring a new idea of democracy and citizenship.

"School textbooks are crucial organs in the process of constructing legitimated ideologies and beliefs and are a reflection of the history, knowledge and values considered important by powerful groups in society." — Crawford, 2003

Nowadays, history textbooks in particular are often a target of national and international debates. As Crawford (2003, p.5) put it, "School textbooks are crucial organs in the process of constructing legitimated ideologies and beliefs and are a reflection of the history, knowledge and values considered important by powerful groups in society."

In the middle of the last century, a school renewal movement questioned the effectiveness of the textbook and opted for a different approach to education that draws from multiple sources and promotes the production of teaching aids by teachers themselves, using a variety of learning resources. Famous French pedagogue Célestin Freinet led this movement and experimented with the adoption of alternative forms of teaching aids in different European contexts (for an example from Italy, see Pettini et al. 1974). Based on the Freinet Modern School Movement, many teachers considered the textbook insufficient and replaced it with the study of other volumes or with direct experience of reality. This teaching perspective is enjoying new success today, as digital learning support is increasingly used to enable more active approaches to knowledge construction.

Box 2-3 Freinet, textbooks, printing press, 'teacher bands' and programming

Célestin Baptistin Freinet (1896-1966) was a French pedagogue who played a leading role throughout the 20th century. Partly inspired by John Dewey, his pedagogy aimed to make the classroom a workshop for free expression by children: free text, free drawing, inter-school correspondence, printing the school newspaper, and so on.

He was critical of the textbook, which "enslaves the child's thinking" (Freinet 1928, p.8). According to him, textbooks "bend all school work to a method, to practices that neither teachers nor pupils have approved or discussed—which teachers sometimes condemn." This idolatry of printed writing "overshadows [the] need for activity and creation" (ibid.).

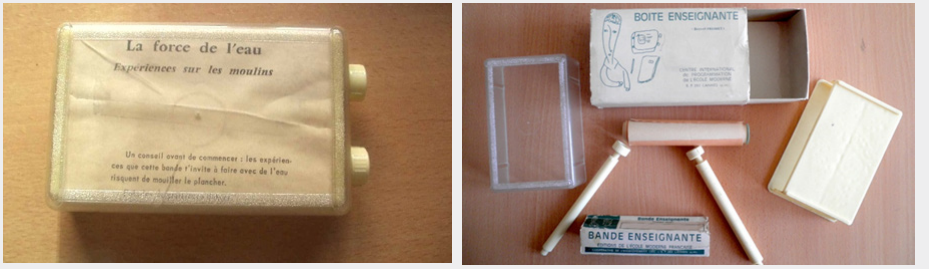
Freinet proposed that students should make their own textbooks with compound texts in the printing press and, as early as 1929, he designed the 'cooperative files'. He introduced the work plan which took into account the heterogeneity of the class group and helped personalize learning. In a situation where students had access to very few books, which summarized and presented a limited view of the world, and made textbooks too often indigestible, he suggested another

working technique in which the child draws his or her knowledge from thousands of books, cards, records, magnetic tapes, not to mention the great books of nature and the social environment from which we will ultimately get our deepest inspirations (Freinet 1937/1964a).

Freinet was in favour of new technologies (radio, cinema, teaching machines), but he opposed behaviourist psychology (Freinet 1964b). For him, "reinforcement" was not enough. Learning requires a deep motivation, not only mechanical and external, but also personal and emotional, which conditions the behaviour experimentally. He stated that "American-style teaching machines are by no means based on a reliable theory of learning; that they are based on a much too primary conception of conditioning, which is only valid for mechanical operations; that it would be a serious mistake to want to use them as they are for intelligent studies; and that there would be a danger of generalizing their use in schools, at least in this form" (Freinet 1964b).

He developed the idea of experimental trial and error (tâtonnement expérimental), with a simple technology: teacher's boxes and paper tapes (Freinet 1963): "Our tapes are short and require only a short work time. But the ones we edit are only a basis for work, the skeleton of our programming. The educators themselves, and their students, will then be able to adapt this basic series to their class and environment by making tapes."[19] With Freinet's 'teaching box' (*boite enseignate*), which is a simple mechanical device, the teacher prepares strips of paper or 'bands' (*bande enseignante*) on rods and the student scrolls them by turning the knobs (see **Figure 2-2**).

Figure 2-2 "La force de l'eau: Experiences sur les moulins", a 'teaching box' on hydropower and mills (left) and a disassembled teaching box and its different elements (right) designed by Freinet



Source: Photographs taken by GL Baron in 2013.

The idea was not to reject the textbook but to multiply resources and technologies. As he expressed before the Second World War, "We are in an era where an excess of knowledge tends to block understanding and culture" (Freinet 1937). This is a recommendation that is apt to be repeated in the era of the Internet. "At a time when the mass of human knowledge exceeds the possibilities of the most gifted individuals, it is essential to prepare children to think for themselves, to seek, to document, to choose, to prepare the answers to the intellectual, technical and social problems that life poses and will pose to them" (Freinet 1937).

Making textbooks with students remains an idea that new technology can help to realize, from early printing presses in schools (1928), to modern collaborative editing software, printing on demand, and 3D-printers.

19 See https://www.icem-pedagogie-freinet.org/node/15504 for how to use these boxes and tapes.

1.2 Textbooks: A diversity of models

In addition to the historical development of textbooks outlined in the previous section, it is important to note that textbooks have adopted very different approaches. Alain Choppin (2005) distinguished seven archetypes or models of textbooks.

1. The **catechetical** model, derived from religious literature, contains a fictional dialogue in which precise questions from the teacher alternate with unique answers from the student (memorization of concepts). Ackermann's manuals[20] published for early independent Spanish America are a characteristic example, "structured as a series of short questions and medium-length answers one after the other, forming chapters" (Roldán-Vera 2001, p.23). These books were designed to be used in family circles rather than at school. The catechetical genre was appropriate for the distribution of knowledge on a large scale.
2. The **apologetic** model has a succession of short stories or apologists chosen and classified from an edifying perspective (inculcation of moral principles). This type of textbook was used in classrooms until the end of the nineteenth century.
3. The **juridical** model, originally used in secondary schools, contains a succession of short paragraphs numbered continuously (concern for scientificity and objectivity, presentation of historical nomenclatures, botanical classifications, mathematical theorems).
4. The **encyclopaedic** model groups all the subjects in the programme, with an organisation that follows the general progress of the year.
5. The **playful or attractive** model combines study and entertainment. Although in Christian traditions learning is rather austere and combining study and entertainment is rare, this genre became established in France after 1865, with books by Jean Macé, in particular Miss Lili's Grammar (**Figure 2-3**), which met with some success. But this genre became widespread in primary schools only at the end of the 1920s, with the incursion of the playful and the invasion of the image.

Figure 2-3 La Grammaire de Mlle Lili[21]

6. The **school novel**, adapted to an encyclopaedic presentation of knowledge, integrating apologetic and encyclopaedic models, is presented as a pretext for a journey of adventures that lead to the emergence of morality or to developments in different subjects.
7. The **integrated** textbook, responding to the increasing heterogeneity of the school population and encouraging student activity, appeared during the 1970s. This represents a profound transformation of textbooks with a more complex internal organization. Abandoning a linear structure requiring continuous reading, these books adopted a reticular structure, interlocking several levels. The teacher finds the elements to use according to his or her objectives and can put the student in a research situation. In short, the integrated textbook is a fragmented book, more suitable for classroom work, but no longer a reference book, a kind of hypertext on paper. It is no longer "a book that we read, but a book in which we read". We thus move from reading to consultation, a mode of approach quite characteristic of electronic books, making digital the obligatory future of paper.

20 Published in London in the 1820s by Rudolph Ackermann for a Spanish American audience, a series of educational manuals were written in a question-and-answer form. These manuals became known as 'Ackermann's catechisms'. See https://muse.jhu.edu/article/3621/summary

21 https://gallica.bnf.fr/ark:/12148/bpt6k5832502x/f5.highres

Paper books have their limitations in terms of giving access to multiple sources and proposing multiple paths according to the wishes or skills of the students. This leads us to a history of e-books.

2. The Emergence of Electronic Books

This section focuses on recent changes in books brought about by computers, the Internet and digital information and communications technologies.[22] Of these, an important project is Project Gutenberg[23], which was started by Michael Hart at the University of Illinois in 1971. The overall philosophy was to make information, books and other materials available to the general public in forms that a majority of computers, programs and people could easily read, use, quote and search. Marie Lebert (2008) traced the history of the project, which now (as of June 2018) offers more than 57,000 free e-books. It costs nothing to read or distribute these digital resources, nor do they require proprietary apps or e-readers to access.[24]

The emergence of new forms of reading supported by computer technologies can be attributed largely to the pioneers of hypertext. Instead of controlling the readers (as we shall see below), these pioneers have sought to extend the possibilities of textual exploration by opening up multiple paths through a set of documents, whether they are conceptualized as personal (Bush 1945), collective (Engelbart 1962) or universal (Nelson 1965) devices. These pioneer works on hypertext, and those leading to Xerox's *Dynabook* (Kay 1972; Kay and Goldberg 1977) and to Brown University's hypermedia systems (HES, FRESS, Intermedia), have had a great importance in the progressive development of the notion of the electronic book (see Timeline 2).

Yankelovich and colleagues (1985) made an interesting comparison between paper books and electronic books. They pointed out that the book is an integral part of our culture. It has many advantages, but it is static and therefore it is not possible to manipulate what it contains. Its static feature is both its greatest strength and weakness. In a book a distinction is made between the *logical structure*, which corresponds to the organization into chapters, sub-chapters and so on, and the *physical structure*, which consists of printed pages. Aids provided to navigate the content include the table of contents and index. Their role is to provide direct access to specific areas in the book. The readers must look up the table of contents or index themselves, find the page corresponding to the information sought, and open the book to that page. An e-book frees the readers from these constraints and from the task of searching for the page. But beyond the ease of access provided by electronic links, the computer allows the book to become dynamic and interactive. Umberto Eco (1996) described how digitalization was creating what he called 'open work', an infinitely rewritable text open to the interpolation of multiple authors: "Every user can add something, and you can implement a sort of jazz like unending story. At this point the classical notion of authorship certainly disappears, and we have a new way to implement free creativity."

E-books offer many advantages: connectivity support, multimedia capacity, dynamism, customization, interactivity, quick information retrieval, history (record of reading), cooperative publishing and alternate spatial orientations, to name a few. But while an e-book offers more possibilities than a classic book, it is more complex for the reader to manipulate, it is more difficult for

22 For an overview of the history of the book, see https://en.wikipedia.org/wiki/History_of_books or in French, with the French National Library http://classes.bnf.fr/livre/arret/histoire-du-livre/premiers-supports/index.htm ; see https://sfbook.com/the-evolution-of-the-book.htm for a series of images of books.
23 https://en.wikipedia.org/wiki/Project_Gutenberg
24 www.gutenberg.org/wiki/Main_Page

its author to create, and requires the development of a complex computer system to be used under the right conditions[25].

Hypertext techniques allow a high degree of multimodal integration and offer connection possibilities between multiple text structures. Some examples of e-book formats include standard books, draft notebooks, workbooks, multimedia simulation supports and multimodal platforms. An electronic book can be defined as an organized body of knowledge on a given subject, which corresponds to a set of interconnected objects such as texts, figures, logico-mathematical models, indices and other relevant artefacts.

With the development of electronic books, new forms of educational resources are also emerging and often demonstrate a synthesis between traditional printed books and learning environments. Indeed, e-books provide integrated environments where the 'book on screen' aspects are complemented by various resources (exercises, simulations, etc.) for autonomous forms of learning.

In recent years, e-books have no longer been confined to university laboratories and are gradually conquering spaces that were once dominated by paper. With the development of multimedia and the Internet, new integrative possibilities are emerging that replace, complement or extend printed books. These entail moving away from the closed aspect (paper book) to the open aspect of digital text (updated via the web). Reading itself is being transformed, becoming a particular form of interaction with a reactive device.

In short, the e-book is based on the book's historical conceptual model, it benefits from multimodal as well as multimedia supplements, and it offers navigation possibilities through hypertext. It is a device that can be configured, be reactive (i.e., capable of responding in different ways to the reader's requests), dynamic or adaptable (i.e., capable of modifying the shape of a page according to the needs of a particular reader or for a specific use), and open (via the Internet).

In this sense, e-books can incorporate elements of control over the reader, which leads to their association with another tradition, that of teaching machines.

There remains this unresolved tension between openness and control in education: Is it a question of returning control of computer applications to the user with the metaphor of the book or of giving the book the ability to control its reading or supposed comprehension?

25 The first e-reader (e-book reader or e-book device), the Rocket eBook, appeared in 1998. See https://en.wikipedia.org/wiki/E-reader

Timeline 2 **Paper textbooks, teaching machines, hypertexts and electronic books: Some landmarks during the 20th century**

Pressey
1926

Skinner
1950

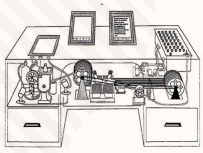
Many teaching machines were produced before the 20th century, even in the ancient times. The left is an example of an old teaching aid from the 1st or 2nd century AD (Buck 1989, p.39).

Teaching machines: control, small steps, stimulation, immediate feedback

Different models: catechetical, apologetic, juridical, encyclopaedic, playful or attractive, school novel, and the integrated textbook...

1900 **1910** **1920** **1930** **1940** **1950**

Paper textbook 1900 to 2005



"As we may think"
MEMEX
Bush
1945

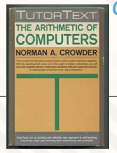
This report includes three timelines. Together they illustrate transitions between worlds that change with the evolution of technologies for knowledge storage and diffusion.

This timeline covers the 20th century. It shows the book competing with other technologies from the industrial society, then the information society, and a strong trend towards the industrialization of education. The book is no longer the only knowledge technology; it needs to be transformed.

AutoTutor
Crowder
1960

Teaching box
Freinet
1964

Scrambled book
Crowder
1958



Textbooks with additional resources on other media than paper: slide photographs, audio cassettes, video cassettes, CD-ROMs, companion websites...

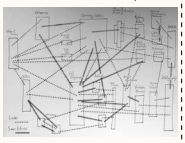
1960 **1970** **1980** **1990** **2000** **2010**

Digital textbooks

NLS Augment
Engelbart
1962

Project Gutenberg: an ongoing effort to digitize cultural works — the oldest digital library founded in **1971**

Dynabook
Alan Kay
1972



XANADU
Nelson
1965

HES (Hypertext Editing System)/FRESS (File Retrieval and Editing System): Intermedia, hypertext prototypes developed at Brown University in the late 1960s, paving the way towards electronic books and widely distributed hypertext systems such as HyperCard (1987) and the World Wide Web (1991)

Computer (electronic) books / hypertexts: openess, links, navigation

Note: The sources of images used in the Timelines are listed at the end of the publication.

3. From Paper Textbooks to Educational Platforms through Teaching Machines

Thorndike (1912, p. 165) provided the following rationale for teaching machines and programmed instruction:

> *"If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print. Books to be given out in loose sheets, a page or so at a time, and books arranged so that the student only suffer if he misuses them, should be worked out in many subjects."*

The idea of designing a book that would somehow control a student's progress would lead to the design of many teaching machines during the 20th century. A teaching machine can be considered as any mechanical device used for presenting a program of instructional material. The most famous are the devices by Pressey, Skinner and Crowder (Ferster 2014; Bruillard in press; also see Timeline 2).

Crowder produced electrical machines for implementing his programming method called branching or intrinsic programming. But he also produced a series of books called 'scrambled books', which dissociate the logical structure from the content and the physical structure consisting of the printed pages (see **Box 3-5** for comparison between scrambled books and the most current digital learning platforms designed to enable personalized learning). Many paper scrambled books have been designed, following the programming principles stated by Crowder: presentation of information followed by a question offering several possible answers, each of which is associated with a page number for continuous reading.

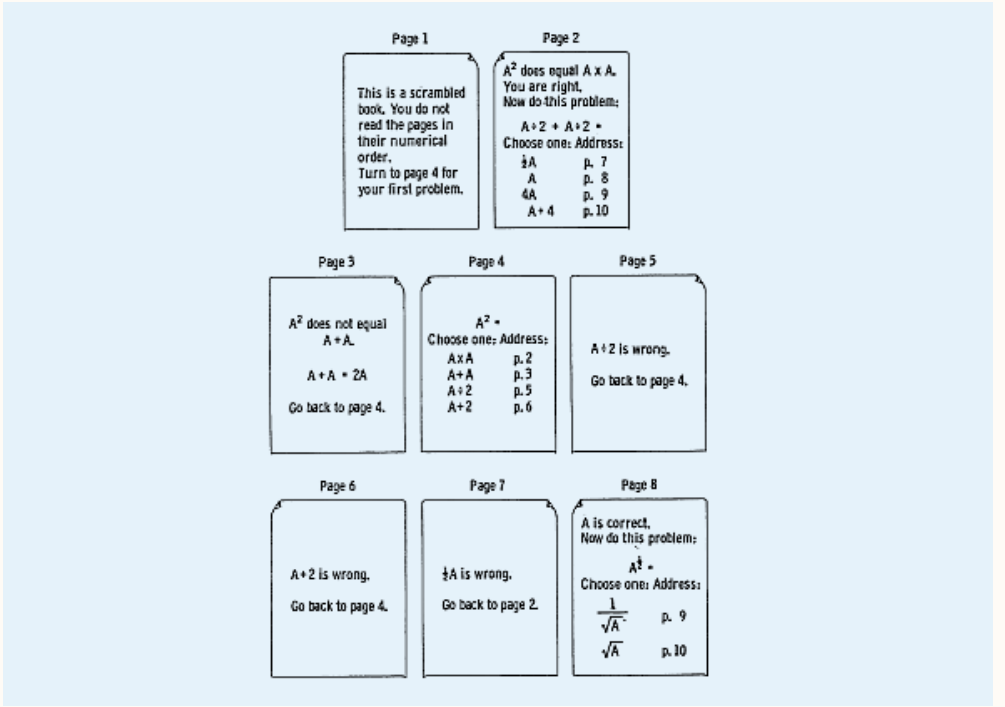
In a scrambled book, each page (or portion of a page) is a unit (see **Figure 2-4**). The student begins on page 1 and is subsequently asked a question to which several alternatives are given. Depending on which alternative he or she selects, the student is directed to a subsequent page where his or her error is corrected or where he or she is introduced to the next part of the sequence (Bruillard 2017). These books, arranged in such a way as to allow particular paths adapted to a learner's progress, have disappeared. They remain only in the form of the 'You are the Hero' books, stemming from fantasy role playing games and the computer games that were modelled after them.

Dissociating logical structure from physical structure and linking them by means of an addressing system naturally led to computers, machines adapted to this task, making it possible to avoid possible 'cheating', and many CAL (computer assisted learning) software programs have adopted the scrambled book model.

Gradually, computers have replaced other teaching machines, allowing the design of adaptive systems and the implementation of generative programs. The rise of computers and the extension of research led to CAI (computer assisted instruction). The increasing complexity of the programs to be built to ensure optimal adaptation to the learner gradually makes it essential to use advanced programming techniques and solutions, at least partially, offered by artificial intelligence (AI). From the 1970s, research has been conducted on intelligent tutoring systems (see Chapter 4 Section 1).

This research stream has made it possible to develop interesting applications for research, but with a still limited impact on teaching. One can predict a sort of rebirth of the teaching machines with new digital machines and their extraordinary capacities—the possibility to capture, treat and analyse a large amount of data (big data), as well as the progress of AI allowing designing very detailed

Figure 2-4 Presentation of a scrambled book (Stolurow 1961, p. 39)



learning models (deep learning). However, there remains this unresolved tension between openness and control in education: Is it a question of returning control of computer applications to the user with the metaphor of the book or of giving the book the ability to control its reading or supposed comprehension?

Resource platforms are being developed and are proliferating, whether they are open and managed by educational authorities, teachers or teachers' associations, school publishers or EdTech companies. They offer educational resources but also services such as recording student progress and results. They can thus serve as a support for digital textbooks by adding additional services around other resources to be studied, exercises to be done while keeping the data, proposing courses, and so on. This leads to a wide range of possible choices regarding how a digital textbook can be designed, interacted with by students, and utilized by teachers, administrators and education systems.

4. Concluding Remarks

In order to understand digital textbooks and their possible future evolution, it is important to adopt a historical perspective. Textbooks are born out of this history of books, with deep epistemological and political roots embedded in them. They are also deeply influenced by the history of teaching machines and emergent electronic books.

The textbook is a complex object; it can serve not only ideological but also commercial purposes, including advertisements of products for daily use such as toothpastes.[26] It is a multifaceted mirror that both reflects and projects programs and activities into classrooms. Yet, the actors who use them also shape the experience with their own interests and questions. The transition from paper to digital raises many questions that we have tried to address in this chapter. As we will show in the next chapter, the issue is not so much the digitization of textbooks *per se*, which would facilitate the transition between different reading materials, but the economic, social, political and cultural changes that accompany digitalization and their impact on education.

As we have seen in this chapter, textbooks have evolved over time. They have always borrowed elements of the technologies of their time. While they focus on synthesis (what needs to be known), very different models have been explored. Thus, to speak of 'traditional textbooks' is often only a manifestation of a sheer ignorance of their diversity. Similarly, criticism levelled against them is often more a critique of teaching methods recommended at a given time, than that of a book itself that has no reason, apart from economic issues, to be the only one kind of educational resource available to teachers and students. Textbooks have taken many different forms, sometimes incorporating visions of controlling the readers and their hypothesized comprehension and progress, borrowed from the characteristics of teaching machines, and at times updated through the properties of digital technologies, giving access to many other resources through hypertext links and the Internet. The next chapter will focus on these developments that lead to the current offers of digital education media and resources.

26 In Brazil, whereas religious advertising is explicitly prohibited, commercial advertising is not. Cristina d'Avila (2001) presents textbooks containing brand logos and slogans and especially writing activities based on these slogans. For example: Copy the sentence in your notebook that has the same meaning: "Kolynos provides pure and refreshing breath" (Kolynos is a brand of toothpaste). Young mothers are also targeted by textbook advertisements.

CHAPTER 3

Digital Textbooks and Digital Education Media and Resources: Definitions, Examples and Emerging Tendencies

The aim of this chapter is to see how to qualify today's textbooks and digital education resources, propose a definition of them, and highlight ongoing changes in textbook production. A collection of digital resources (see Appendix I) has been compiled by an international expert group convened by UNESCO MGIEP, and is presented in categories that were deductively established based on reviewing the main audience, aims and functionalities of these resources. Additional resources have been also briefly discussed to have a better overview of digital education resources in circulation. Such categorization makes it possible to highlight some major trends. Finally, the chapter calls attention to a possible change in the design of textbooks adapted to the current educational context.

1. How to Define Digital Textbooks? And Digital Education Media?

The textbook is becoming less and less a part of the world of print and more and more of the world of multimedia and the Internet. Understanding the historical development of these resources makes it possible to envision a future that is not radically innovative. New tools influence the design, structure, distribution and use of printed textbooks. However, the prevailing model of the paper textbook acts, undoubtedly in a most often unconscious but real way, on the structure and presentation of the new teaching and learning tools.

The traditional book model is being challenged by digital technologies. How to reconcile the advantages of books with the functionalities that digital technology can offer?

Digital textbooks can be considered as a subset of digital books. So, the first question is what currently constitutes a book: Is it a physical object in a print form with a cover? A file (PDF, ePub or other) that can be read with a reader? Or, can a book be a service that is consulted on the Internet? Books seem to be shifting away from physical objects that we can purchase and use as we wish, towards digital objects we can use by citing their origin without acquiring ownership (free licenses) and services that we can rent for a certain period of time. New business models for textbooks are following the general global trend of transitioning from a product focus to a services focus.

Alan Liu, Head of Transliteracies research project at the University of California Santa Barbara[27], defines a book in the Digital Age as a long form of attention intended for the permanent, standard, and authoritative, that is, socially repeatable and valued, communication of human thought and experience (usually through narrative, argumentative, or other programmatic organizations of bound-together-yet-discrete textual, graphic and haptic[28] elements) (Liu 2011, 2012a, 2012b). In Liu's vision, a book is defined by its audience. This is typical of today's Internet and the need to capture attention. This is, however, not yet an issue for schoolbooks, which are regulated differently. This definition cannot be applied to textbooks, as more stable objects aligned with planned curricula and adapted to teachers and students are needed. Isn't it the traditional book model that is being challenged by computer technologies? For school work, is it necessary to have coherent units reflecting the thinking of one or more expert authors (books in the classical sense) or are more independent, sometimes disparate, sets of documents preferable that teachers modify and assemble according to their desires or the needs they perceive for their students?

There are at least two perspectives to consider: that of traditional school publishers who value books because they see their added value in text, images and the general structuring of content in alignment with planned curricula, and that of EdTech companies, or developers of digital content in general, whose added value lies in the new functionalities they can offer.

1.1 From hyperbooks to digital textbooks

Many textbooks are based on a strong organization, each chapter following the same structure (situations, courses, essential to remember, exercises with different levels, etc.) and sometimes with

27 Research in the Technological, Social, and Cultural Practices of Online Reading. See http://transliteracies.english.ucsb.edu/category/research-project for details.
28 Perception and manipulation of objects using the senses of touch and proprioception

the 'dictatorship' of a double-page spread[29]. With increasing diversity in student bodies in many parts of the world, the question has arisen about the need to introduce differentiated pedagogy, that is, tailored for each student or each group of students. How can such a pedagogy be translated into a paper textbook? Textbook designers tried to propose reading paths (but without using the techniques of scrambled books, see Chapter 2), with means such as colour coding, which required the insertion of instructions for use for these textbooks. In a way, this required making hypertexts on paper but paper did not allow this to be done properly, showing the limits of this old model of textbook.

In addition, hypertext research invited readers to switch from free navigation —which left them to activate the links they wanted—to a more guided navigation. This raises an important debate between the traditional linearity of frontal teaching and textbook reading, and the multiplicity of paths offered by hypertext.[30]

At the end of the 1990s, in follow-up to research on e-books, researchers developed hyperbooks, or hypertext books, referring to a hypertext that has some of the characteristics of a printed book (Falquet et al. 2009). In particular, a hyperbook is organized as a set of elements that are grouped together to form larger entities such as chapters or sections. Hyperbooks also offer a management of reading paths that could be based on relationships between concepts. For example, Falquet et al. (2001) developed a model for creating, managing and viewing the contents of the hyperbook, leading to very technical textbooks.

Around the same time as highly technical hyperbooks appeared, considering the potential of hypertext technology and computer-based learning and teaching, Bruillard and Baron (1998) called for rethinking the complementarities between books and the IT environment, and devising tools to allow teachers to link theory, objectives, knowledge gaps and misconceptions of students with activities. It seemed essential to be able to provide teachers with software integrators incorporating a pedagogical theory. However, Bruillard and Baron observed that there were still neither digital tools nor the necessary culture at that time, and concluded that it was important to develop specific authors' skills to enact active pedagogy in digital textbooks.

How to reconcile the traditional linearity of frontal teaching and textbook reading, and the multiplicity of paths offered by hypertext?

Things have, however, evolved in a way different from what Bruillard and Baron (ibid.) envisioned two decades ago. The textbook, before being a digital object, is first and foremost an economic object. The worlds of school publishing and IT industry are very distant, and it takes time to bring them together. They do not have the same business models, the same ways of compensating authors, the same ways of organizing, or the same culture.

Digital educational media[31]—a broader category that encompasses digital textbooks—cannot be given a restrictive definition. There are many resources specifically designed for education, and many other resources that were not originally designed for educational purposes but that are used in an educational context. There is no *a priori* limit; everything depends on the imagination

29 A double-page spread is often the basic unit of textbooks: "The layout of the various elements of the double page, textual and iconographic, are arranged in a recurrent manner; texts, scientific speeches or documents must not exceed a scrupulously predetermined number of typographical characters, whatever the subject matter; the number and size of photographs, drawings and diagrams, their positioning in the double page, the wording of legends also comply with pre-established rules. The production of a school book is now a compromise between structural logic, economic logic and the pedagogical and didactic logic specific to each discipline, a compromise that considerably restricts the author's initiatives, in the traditional sense of the term, and which can sometimes leave him with some bitterness" (Choppin 2005).

30 See, for example, Nelson (1970), who blames teachers for what Freinet blames textbooks.

31 The term media generally refers to a means of distribution, diffusion or communication of documents or messages, such as radio, television, cinema, the Internet, the press and so on. In the expression 'educational media', to simplify, we often confuse the media with what is transmitted, otherwise we could say educational media and resources.

of educational designers or teachers. In its project on digital learning resources as systemic innovation[32], the OECD defines digital learning resource as "any digital resource that is actually used by teachers and learners for the purpose of learning".[33]

When it comes to digital textbooks, a plausible definition does not seem to exist. Are they a portable device or an internet service, a digital 'schoolbag' (including personal digital assistant, mobile devices and so on), complementary to or a substitute for paper textbooks? One way to define a digital textbook can be to take into account what publishers propose. For reasons of cost and expertise, publishers are not likely to take over hyperbooks, but will offer products that are more a continuation of paper textbooks. Digital textbooks are then considered as electronic versions of traditional print textbooks used in schools and colleges[34], that can be read on a computer, netbook, smartphone or e-reader[35], that are used to teach a variety of subjects to students with and without disabilities.[36] As Sylvie Marcé (2003, p.119) put it from a publisher's perspective, "Publishers provide a service for emerging needs. Nor do they do the programs (prescribed curricula), they do the practices. However, they are on the lookout for developments, whether they are pedagogical (research) or technical (new technologies). To this extent, they can initiate new practices or contribute to their development" (original in French, translation by the editors).

In France, textbook publishers have begun to develop digital products mainly from 2008 on. Thus far, three 'generations' of digital textbooks have been successfully developed (Bruillard 2015):

1. Simple digital textbook, mirroring the paper textbook, which was marketed from 2008 or even earlier (PDF version of the paper textbook)
2. Enriched digital textbook, launched in 2009, which also contains multimodal enhancements such as audios, videos and animations
3. The 'third-generation' digital textbook marketed from 2011 on, which offers teachers the opportunity to mix textbook resources and personal resources, and includes interactive exercises.

All of these tools are intended to be integrated into the collective use as the class textbook, and are primarily for teachers who can project it in the classroom for all the students to see[37]. It is interesting to note that, according to a national experiment in France with digital textbooks (Bruillard 2015), in digital textbooks designed along the lines of printed textbooks, enrichments provide real value yet tend to be too modest, with interactive features being limited or absent. The digital textbooks offered in France, at least until 2012, were thus mainly improvements of paper textbooks that included some new features and utilized an economic model still in line with paper products. Similar patterns have been observed in other countries as well, such as in Hungary (see **Box 5-4**).

With 'third-generation' digital textbooks (such as the Lib, *Livre interactif* or Interactive Book[38]), teachers can modify the textbooks, adding and editing documents, text or pages, and create their own courses from a customized textbook. Among the provided functionalities, one can find a toolbox that includes a highlighter, arrows, zoom tools, screenshots and annotations; multimedia supplements such as animated maps, interactive diagrams, videos; and the opportunity to "Share your modified pages with your fellow teachers". This kind of digital textbook can address the requirements of teachers to adapt educational tools for their students and to the overall context of

32 http://www.oecd.org/education/ceri/moreabouttheprojectondigitallearningresourcesassystemicinnovation.htm
33 http://www.oecd.org/education/39275179.pdf
34 https://www.wisegeek.com/what-are-digital-textbooks.htm
35 http://drs.dadeschools.net/AdditionalReports/LiteratureReviewonDigitalTextbooks.pdf
36 http://atwiki.assistivetech.net/index.php/Digital_textbooks
37 In France, as the main target is the teacher, the definition of a digital textbook is a product for teacher use.
38 Lib are digital textbooks (from the French publisher Belin Education), interactive and customizable, which can be downloaded to a computer.

their teaching. Nevertheless, certain legal limitations remain, with new economic models following the global transition from products to services. Digital textbooks are typically offered as limited services, accessible only as long as payments are made). However, the development of OERs provides a new alternative model for the design and dissemination of digital textbooks, as discussed below.

1.2 Emergence of OER (open educational resources)

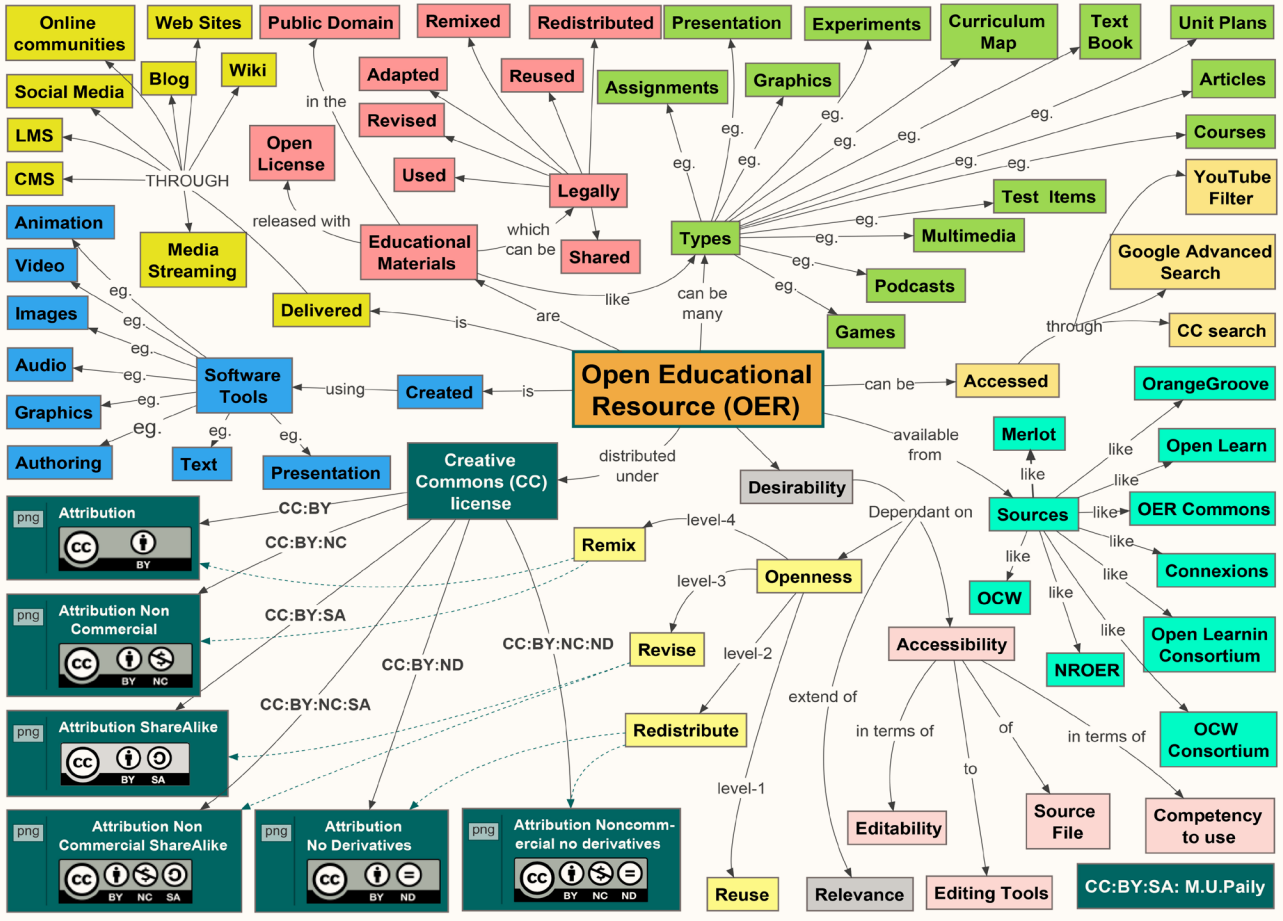
According to UNESCO[39], "Open Educational Resources (OER) are learning, teaching and research materials in any format and medium that reside in the public domain or are under copyright that have been released under an open license, which permit no-cost access, re-use, re-purpose, adaptation and redistribution by others." **Figure 3-1** provides a concept map of OER including the different aspects to be taken into account: type, creation, distribution, licenses, sources, access and so on.

The term Open Educational Resources (OER) was created at the 2002 UNESCO Forum on the Impact of Open Courseware for Higher Education in Developing Countries. Since 2002, the idea of OER has grown considerably, mainly in distance and higher education. Many OERs have been used primarily by "teachers or learning designers that orchestrate the learning transactions", and this focus on learning resources, rather than learning processes, has been criticized as reinforcing "an institutional model that is, in many ways, closed" (Dron and Ardito 2018, p.8). As the use of OERs can be a relatively straightforward ameliorative response intended to lower development costs as well as direct costs to the student, educator, institution or funder, it may not necessarily be connected to any pedagogical, cultural or political improvements (Hodgkinson-Williams et al. 2017). Hoosen and Butcher (2019) observed that OER approaches or initiatives still appear to be an 'add on' in education systems rather than being part of a mainstream approach to creating and adapting materials. One notable exception to this trend is observed in Norway, where the Norwegian Digital Learning Arena (NDLA)[40] is a large publicly-funded OER initiative which provides upper secondary schools with a broad range of digital learning resources (also see **Box 5-3**).

On 25 November 2019, UNESCO's General Conference adopted a Recommendation on OER, making an important step towards quality education and access to information for all. This new Recommendation will support the creation, use and adaptation of OER, and facilitate international cooperation in this field. It also aims to develop supportive policies and sustainability models for OER.

39 Draft Recommendation on Open Educational Resources, 40th session of UNESCO General Conference (40 C/32) https://unesdoc.unesco.org/ark:/48223/pf0000370936
40 https://om.ndla.no/about-ndla/

Figure 3-1 Conceptual map of Open Educational Resources (OERs)



Source: https://commons.wikimedia.org/wiki/File:OER_Concept_Map.jpg

OERs have a largely untapped potential to improve the quality of education, going much beyond remedial measures for enabling access to content often seen in developing countries (see **Box 4-6** for an example from India, and **Box 5-11** for the cases of Kenya and Uganda). The possibilities of OERs in transforming pedagogy are just beginning to be explored. In their Research on Open Educational Resources for Development (ROER4D), Hodgkinson-Williams and Trotter (2018) have taken up Nancy Fraser's Social Justice Framework to better understand OERs and related practices in the Global South. They consider using OER 'as is' (copying) and translating OER uncritically insufficient, thereby advocating a more deliberately 'pluralist' perspective: to re-acculturate educational materials and pedagogical practices, to create or remix OERs that critically engage with and challenge hegemonic perspectives, and make these new or adapted OERs available publicly.

As the example of ROER4D clearly shows, the concept of 'openness' covers much more than open access. While still at a nascent stage, OERs do have innovative uses in school education. Not only do they provide additional free resources, they also open the way for new business models and new forms of textbook development. The case of the Sésamath association, and what it has helped launch, is exemplary (see Bougon et al. 2013)[41]. As outlined in **Box 3-1**, the Sésamath association developed a model of collaboratively creating open school textbooks, which has been taken up by other organizations internationally.

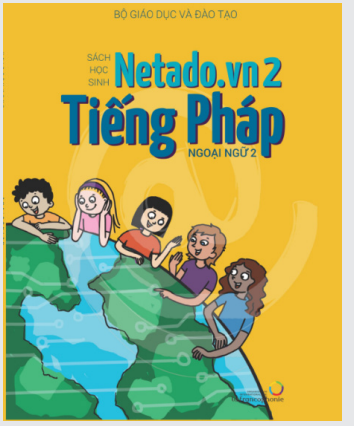
Box 3-1 Exemplary work in developing open school textbooks

Founded in 2001, the Sésamath association's objectives were to create pedagogical resources accessible to as many people as possible for the teaching of mathematics. In 2007, it produced an open textbook (for grade 7), with a free online and paid for in paper format, that was 40-50 per cent less expensive than its competitors. The association has developed expertise in the collaborative creation of school textbooks.

As the educational resources made available by Sésamath France are under free licence, the question of their adaptation in other French-speaking countries arose quite quickly, and these have been done in countries such as Switzerland, Haiti, Morocco and Canada.[42]

The OIF (international organization for the French-speaking world) swiftly supported this extension and Sébastien Hache, one of the three co-founders of Sésamath, became involved in the production of new free textbooks (Hache 2018): the Iparcours[43] math textbook collection (2015)[44] and the Netado project. The objective of the Netado project, being done in partnership between the Ministry of Education of Vietnam and OIF, is to build a whole collection of free textbooks for the teaching of French (as second language). As with the Sésamath or Iparcours textbooks, the team of authors for Netado not only designed

Figure 3-2 Netado project: collection of free textbooks for the teaching of French in middle and high school (http//netado.vn)



41 Sésamath history (in French) : https://fr.flossmanuals.net/sesamath-mode-demploi/historique/
42 http://revue.sesamath.net/spip.php?article575 Sesamath : Une constellation de Sesamaths francophones.
43 http://www.iparcours.fr/
44 Free textbooks on line, see for grade 6: http://www.iparcours.fr/ouvrages/ouvrages.php?ouvrage=Manuel62016

and wrote the pedagogical scenarios, but also designed the layout of the contents in an editable formatThis can be seen as a new textbook publishing model.

'Massive' collaboration is the main feature of Le LivreScolaire[45], which presents itself as producing the first paper and digital textbooks co-created by 3000 teachers. The LivreScolaire is based on three pillars: collaborative (interactive participation of hundreds of colleagues in the process of textbook production), free (free online textbook), and digital (textbooks in the form of a website, with additional features such as interactive maps and a mode adapted to dyslexics). The business model is based on the sale of paper books and premium digital subscriptions. Authors are remunerated by copyright.

In these examples, the traditional paper textbook model remains at the heart of the design, even if it is enriched. Nevertheless, *it is the design process itself that has changed*: teams of authors may have at their disposal several different collections of textbooks under free license; large and remote teams may collaborate; authors may design a digital object that can be directly printed.

The development time for each of the successive textbooks of the Netado project (see **Box 3.1**) has decreased significantly as the team has become more experienced and has the benefit of a greater number of textbooks under free license[46]. According to Sébastien Hache, they could even adapt the Sprint book processes, that is, the design and production of books, in a few days to produce Sprint Textbooks. The open textbook *British Columbia in a Global Context* was written in four days by a small team of geographers and assistants[47]. Other examples can be examined on the Booksprints website[48].

Such a process can be useful in adapting textbooks in specific countries and cultures, working with local teachers. This may address the limitations highlighted in the ROER4D project. On the one hand, full participation in the OER movement in the Global South requires infrastructural support, legal permission to share materials and OER curation platforms (Hodgkinson-Williams et al. 2017). On the other hand, for an in-depth contextualisation, technical and pedagogical support are required for the creation and adaptation of OER produced in the Global South. In any case, producing digital textbooks locally can help to enhance the agency of teachers, and (re)invigorate their autonomy and role in improving the quality of education.

45 https://www.lelivrescolaire.fr/
46 https://fr.flossmanuals.net/realiser-des-manuels-sous-licence-libre-retours-dexperiences/_draft/_v/1.0/preambule/
47 https://bccampus.ca/2014/06/20/how-to-turn-a-great-idea-into-an-open-textbook-in-just-four-days/
48 https://www.booksprints.net/

2. Mapping Existing Digital Textbooks and Digital Education Media

After having described recent trends both in digital textbooks and educational digital resources and in their modes of production, it seems worthwhile to present a diverse array of existing digital products to help understand better the characteristics of the current offer.

2.1. Sampling digital education resources

As a precursor to this review report, UNESCO MGIEP invited experts, institutions and publishers from across the world to share and suggest digital educational resources. An attempt was made to first collect as many resources, platforms and artefacts as possible; then these resources were sampled using a mix of purposive and snowball sampling methods (Bryman 2004; Scott and Morrison 2005). As a consequence, some popular, and arguably exemplary, digital educational resources may have escaped this review. The attempt was to select diverse resources drawn from:

a. Different subjects, disciplines and levels
b. Different languages and geographies
c. Different levels of alignment with formal education, i.e., fully aligned, somewhat aligned, and not aligned with curricula
d. Different publishers: government, commercial and independent initiatives
e. Different genres.

In total more than 80 resources were reviewed. The objective of this section is to get a general idea of the state-of-art of digital educational resources in circulation and highlight some of their characteristics in relation to digital technology.

2.2. An overview of sampled resources: Target audience and subject areas

The sample collected can be broadly described in terms of target audience, subject areas covered and countries of origin. In Chapter 4, another dimension of analysis will address the pedagogical form of the resources. In terms of target audience, most resources (including braille-enabled resources) were designed to be used in K-12 education. The balance was meant for higher education and teacher education. Of the resources for formal education, more than half are aligned with curriculum and contribute to a subject in terms of the contents and skills defined in the national or sub-national (state or provincial) curriculum. Resources on mathematics are over-represented. Publishers and content creators often produce content serving many countries, catering to monolingual, bilingual and multilingual users. In the sampled resources English dominated in the monolingual category, followed by Spanish and Portuguese; Spanish, Chinese, French, Hindi and Swahili dominated in the bilingual; and Spanish, French, Chinese, Hindi and German dominated in the multilingual categories. Although the range of resources is not equally represented by countries, the resources sampled present a substantial list distributed through South and North America, Europe, Africa and Asia, comprising 26 countries (USA and Mexico being over-represented). The distribution of the resources is skewed, partly reflecting the composition of the expert group convened by UNESCO MGIEP. The experts chose the sources based on their language skills and knowledge of the regions and countries, which resulted in a high percentage of English and Spanish resources.

2.3. Categorizing sampled resources

Collecting a set of resources made it possible to explore how to organize them. The development of a categorization was partly inspired by a classification of IT tools in education. Bruillard and Baron (2018) distinguished three groups of IT tools.

- Software tools used in the study of the different subject matter and specialized software systems prescribed or selected by teachers and acting either for monitoring students' progress or as simulation and discovery tools, providing new user experiences (e.g., virtual reality, immersive education.)
- Digital resources of various granularities that may either be directly used by teachers to illustrate their courses or be prescribed to students. This idea of resource has been an area of significant development in the past two decades, under an extremely wide range of forms: Wikipedia and Wikimedia, new interactive textbooks, video capsules, shared curricula designed by individual teachers or by associations of activists
- Learning platforms, including MOOC platforms[49] (often used in distance education).

In the context of digital educational media, a similar classification can be proposed:

1. **Digital textbooks:** Examples include e-books
2. **Multimodal resources:** Examples include videos, infographics, animations, podcasts (audio), websites, blogs, wikis, games, slideshows, augmented reality applications, virtual reality applications, mobile device applications, and OERs
3. **Learning environments (teacher-student interaction spaces):** Examples include MOOCs, social networks sites, and learning management systems.

   In the remainder of this section, some of the sampled resources are described briefly for illustrative purposes in terms of aims, purposes and specific functionalities. Pedagogical aspects are presented in Chapter 4 and case studies of implementation in Chapter 5.

   Some explanations are needed to clarify the three categories listed above. The first concerns resources related to academic education covering the notion of textbooks (with one or more levels and focusing on a single subject/discipline). The second category concerns tools that can be used at different levels relatively independently. These can be tools associated with a particular discipline (such as mathematics), collections of tools, e-books or resources, or a portal providing access to a plurality of resources. The third category includes resources that can be used via a platform that can offer additional services such as discussion forums, keeping track of students' tests and successes, proposing new exercises or resources, providing a dashboard for teachers, and so on.

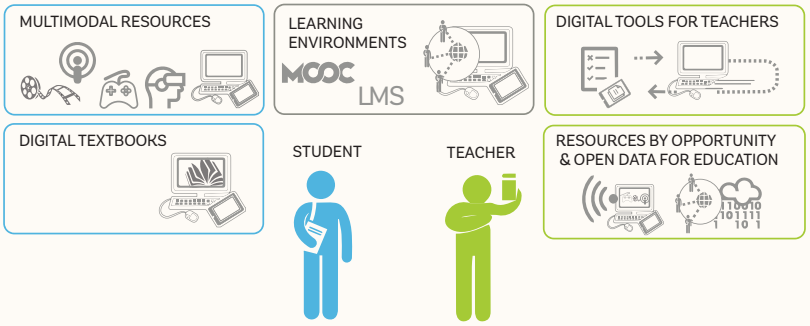
In addition to the three categories introduced above, the sampled resources can belong to an additional category that does not concern students directly. This includes

4. **Digital tools for teachers, such as lesson plans, assessment or evaluation tools:** Some specific assessment tools are not for teachers but for institutions at sub-national, national or international level.

49 Well-known MOOC platforms include Coursera (https://www.coursera.org), edX (https://www.edx.org), FUN (https://www.fun-mooc.fr), Iversity (https://iversity.org), MiriadaX (https://miriadax.net/home), and FutureLearn (https://www.futurelearn.com). MOOCs have start and end dates and are delivered by instructors. Students are expected to submit assignments to be reviewed and marked by the teachers and/or peers. It is similar to how a course is delivered in a conventional education setting, except that students can be anywhere to take these courses.

Finally, a fifth category was added to discuss other kinds of digital education resources that were not sampled.

5. **Resources by opportunity and open data for education:** This category covers resources that were not initially designed for use in a teaching context but teachers decide to use for educational purposes, along with open data for education, which is important in the context of monitoring progress towards achieving SDG 4.



For many resources, the boundaries of categories seem blurred. The sampled resources have been grouped into categories above based on the primary intended usage of the resource. Some resources may fit in more than one category. For example, although Minecraft: Education Edition offers an option of connecting with the online Minecraft Education community members, Minecraft certified educators and Minecraft mentors, it was categorized as a multimodal resource. Khan Academy too was categorized as a multimodal resource.[50] Included in the learning environments category are MOOC platforms and learning management systems (LMSs), which host courses, provide learners with course material such as lecture videos, study material and problem sets, and have purposefully built interactive user forums into their design.

Current digital textbooks are typically not 'born digital' and are designed to function as supplementary resources to paper textbooks.

(1) Digital textbooks

This category includes digital textbooks by publishing houses. Temporary access to resources was provided by large textbook publishers such as Macmillan Education, Westermann (Germany) and Vicens Vives (Spain). UNESCO MGIEP and the experts convened by it approached many publishers but only a handful of publishing houses agreed to provide temporary login to access their commercial digital products. Confirming the observations made earlier in this chapter, none of the digital textbooks sampled was 'born digital'; they were designed to function more as supplementary resources to paper textbooks.

For example, BiBox DEins 5 Gymnasium is a digital textbook—corresponding to the enriched digital textbooks and the 'third-generation' textbooks discussed earlier in the chapter (see 1.1 in this chapter)—developed by one of the largest German publishing companies. It offers a comprehensive digital package of numerous materials and the digital textbook, with both online and offline content delivery. It is a digital version of the printed textbook and can be used like a paper textbook but on digital devices (e.g., on tablets or computer screens as an e-book). The e-book is available

50 The founder of Khan Academy himself claimed that it is not a MOOC. Khan Academy has no start or end dates and its videos and interactive exercises are not presented as courses but more as challenges and tutorials. See https://edtechmagazine.com/higher/article/2013/04/does-khan-academy-pass-mooc-duck-test

in two versions, a student version and a teacher version. The student book comes without any additional material, whereas the teacher's version includes material such as work sheets, the option of uploading own material, assignments, videos, pedagogical explanations, interactive quizzes and exercises. The teacher can insert these enrichment materials on the pages of the book, which gives him or her the opportunity to open it in front of the class. The software also includes a virtual classroom. By using it the teacher can assign different additional materials or exercises to individual students.

Another example is the Complete English Basics series (Third Edition), published in 2017 for Australian schools. This is a Year 7 to 10 English workbook series designed to support junior to middle secondary students with essential language and literacy skills. It is comprised of four printed workbooks plus the option of a fully digital product—an auto-marked interactive version that students can use to practice their skills independently.

A digital textbook of ancient Greek[51] is also available, intended for schools as well as for a wider audience. In Canada, BC Open Textbook Project, in its first phase launched in 2012, aimed at creating a collection of open textbooks aligned with the 40 highest-enrolled subject areas in British Columbia. Today BCcampus,[52] a publicly funded organization that supports the work of the post-secondary system in teaching, learning, educational technology and open education in British Columbia, makes open textbooks available under a Creative Commons license. According to current estimates by BCcampus, 610 faculty members in 40 institutions in British Columbia are adopting open textbooks, reaching 135,000 students and saving 13 million student-dollars (in Canadian dollars).[53]

(2) Multimodal resources

This category includes independent multimodal resources that have been developed by various entities such as a university media lab, a gaming company, and a non-profit and civil society organization. In this category, there are resources that focus on specific subject areas, especially mathematics, statistics and languages, as well as resources that can be used for multiple subjects. Additionally, a number of resources target the so-called '21st century skills'.

Popular digital learning resources include programs such as Scratch and Minecraft. Scratch was developed as a project of the Lifelong Kindergarten Group at the MIT Media Lab to teach children how to code in a fun, children-friendly form. According to its website, "Scratch helps young people learn…essential skills for life in the 21st century." Available now in more than 40 languages, it teaches users to program their own games, animations and stories. Although it was designed to target 8 to 16-year-olds, it is appropriate for all age groups. Minecraft: Education Edition claims to be "an open-world game that promotes creativity, collaboration, and problem-solving in an immersive environment where the only limit is your imagination". It provides content for Math, Science, Language, Arts, History and Visual Arts for years 3 to 14+. Specific subjects are taught by each game with a unique lesson plan, discussion and space for writing notes and reworking lessons. Different games can have different objectives, such as fostering spatial thinking in mathematics using pixel art, with an educator as a facilitator in the classroom. It provides for collaborative projects as well. Scratch and Minecraft can be considered to be virtual analogies to Playmobil (a storytelling game) and Lego (a construction game), respectively.

51 Wilfred E. Major and Michael Laughy. *Ancient Greek for Everyone*. Creative Commons.
52 https://open.bccampus.ca/
53 https://open.bccampus.ca/advocate-for-open-education/open-textbook-stats/

Given that designers of digital resources tend to come from disciplines such as mathematics and computer science, it is not surprising that many resources focus on mathematics. For example, Math Insight is a website providing qualitative descriptions and interactive applets to explore mathematical concepts. It is an advanced mathematics resource targeting university level learners. Mathematicians from University of Minnesota and Iowa State University curate this resource. Immersivemath is "The world's first linear algebra book with fully interactive figures". MIT's Mathlets is "a suite of carefully designed and highly interactive Javascript applets" intended for students to learn about differential equations, calculus, probability and statistics. It outlines three modules for training—mathlets in lecture, group work and homework, and provides demos for different mathlets. Math is Fun is an online math practice platform that covers basic mathematical concepts such as numbers, operations such as measurement, algebra, geometry, and advanced concepts of data, calculus and even physics. Its content comprises curriculum from Kindergarten to Year 12. It provides games, activities, puzzles, math dictionary and worksheets.

In addition to resources focusing on specific subject areas, the expert group sampled resources focusing on building citizenship skills associated with SDG 4.7. For example, DQ World is an animated online game that takes learners through a process of developing digital intelligence (DQ). It is intended to provide a fun and safe e-learning platform for children to be empowered with the eight core DQ competencies, including knowledge, skills, attitudes and values needed to participate safely and responsibly in the online world. iCivics provides free online educational games and lesson plans to promote civics education and encourage students to become active citizens. The German portal Konsumspurenis designed to teach 7 to 11 grade students how to protect climate through the Consumption Traces interactive and action-oriented modules. The central themes of sustainable consumption covered are smartphones and technology, plastic and packaging, mobility, nutrition and fast fashion.

Repositories of OERs

The expert group also sampled a number of OER libraries. For example, OER Commons is "a public digital library of open education resources" from the United States launched in 2007. The platform provides access to OERs that are either in the public domain or are licensed under Creative Commons. It was developed to serve curriculum experts and educators in discovering OERs and collaborating on the use, evaluation and improvement of those materials. It facilitates building of OERs, lesson plans and course modules, individually and collaboratively, with a focus on STEM literacy.

OER repositories can be found internationally. The OER World Map[54] collects and visualizes data in the field of open education worldwide. It is intended to "provide the information needed to support the self-organization processes of the OER movement"[55]. An interactive world map provides information about relevant organizations, projects and people, and allows the identification of OER collections. In OER repositories, some languages are dominant (English, Spanish[56], French[57]), but other languages are present, such as Mandarin Chinese (Netease Online Open Courses)[58] and Portuguese (RIVED – Rede Interativa Virtual de Educacao[59] and MEC RED –Plataforma MEC de Recursos Educacionais Digitais[60]). **Box 3-2** details some of the measures taken to ensure the quality of a multilingual OER portal called TEMOA, from Mexico, which hosts more than one million resources.

54 https://oerworldmap.org/resource/ Pplatform developed by the North-Rhine-Westphalia Library Service Centre with graphthinking GmbH, with cooperation of the Open University (UK). The project is funded by the William and Flora Hewlett Foundation.
55 https://oerworldmap.org/about#the-vision
56 See, for example, Repositorio Institucional del Tecnológico de Monterrey https://repositorio.itesm.mx/
57 https://bneuf.auf.org/
58 https://open.163.com/
59 http://rived.mec.gov.br/
60 https://plataformaintegrada.mec.gov.br/home Also see Box 3-6.

Box 3-2 OER Portal TEMOA: a digital library for improving the quality of education (by M. Gómez-Zermeño and L. Alemán de la Garza)

The word Temoa comes from the Nahuatl language; it means to seek, investigate and inquire. The meaning of this word is reflected on the TEMOA knowledge hub (http://www.temoa.info), a repository that provides a multilingual public catalogue of collections of OERs to support the educational community. TEMOA's mission is to improve educational practice and support closing the gap in global education (Ramírez 2007). To achieve these purposes, it promotes among teachers at all educational levels the adoption of OERs, the exchange of learning experiences in their use, and maintains a high quality in variety, utility, reliability and availability of its directory of OER.

TEMOA also aims to support the reform of basic education carried out in Mexico since 2008, which specifies that the student must be at the centre of the educational intervention in a model of competence development, complemented, amongst other factors, by the use of pedagogical materials and technology in the classroom. Following this target, TEMOA provides reliable OERs that respond to the educational needs of students, teachers and institutions (López, García and Gómez-Zermeño 2016). It seeks to aid the educational community to find resources and materials that meet their needs for teaching and learning, through a specialized search system and collaborative social tools.

Since its inception, TEMOA's developers considered literature review and consultation with education experts to meet the educational aspects of the portal, as well as with librarians and information technology developers for the technical and technological aspects that determine the methods of development, preservation, organization and presentation of information (Fernández, Gómez-Zermeño and Pintor 2016). The catalogues of the selected OERs are described and evaluated by an academic community, categorized by the area of knowledge, education and language, among others. TEMOA also provides a user-friendly search engine, through intuitive filters, and it allows the creation of communities around educational resources.

In the TEMOA knowledge hub, OERs represent a digital information object that can generate knowledge, skills and attitudes in correspondence to a training need of the subject (Ramirez 2007). Today, OERs integrate various types of digital objects among which are full courses, modules, lessons, books, videos, tests, software and any other educational tool or teaching technique to provide free access to knowledge. OERs can be found in formats such as JPEG, PNG, MP3, PDF, HTML, WAP and FLASH (Gómez-Zermeño 2012; Gómez-Zermeño and Franco 2018). TEMOA considers the following to be the types of materials included in this concept

- Text documents such as books, essays, textbooks, book chapters and research papers
- Images, illustrations, graphics, and photos
- Audio-visual materials, such as interactive multimedia, conferences, class extracts
- Software, such as desktop applications.

A group of Open Education experts carried out a TEMOA case study for which they interviewed key informants to understand TEMOA's suppliers, the cataloguing process, metadata and the classification schemes they apply. They also reviewed information regarding the adoption of OERs for the teaching-learning process. The results showed that the concept behind OERs is not entirely new in the context of education. Teachers often share materials with peers, and peer reviews are based on similar underpinnings of open collaboration. The novelty of this initiative lies more in the ease with which the use of ICT allows the OER to be generated, distributed to mass audiences via the Internet, and the legal security that free and open content licenses afford authors and users.

Key informants described TEMOA as a factory with different well-identified processes that must result in a final product quality (Alemán, Sancho and Gómez-Zermeño 2015; Velázquez, Gómez-Zermeño and Alemán 2017). The resources are provided by teachers and peer reviewed by auditors, after which they are organized by a team of experienced professional cataloguers in libraries, coordinated and supervised by a chief librarian. The participants interviewed explained the four stages of the review process to ensure the quality of the OER listed in TEMOA, with each stage represented by the following actors.

- Contributors: Called experts (mostly represented by teachers) because they have experience in an area of knowledge that allows them to suggest the OER.
- Auditors: Responsible for reviewing the contributors' submissions, formats and content; act as a first filter, checking spelling and writing, and whether the OER meets the validity criteria.
- Cataloguers: Professional librarians, they refine the OER description initially provided by the contributor and subsequently revised by the auditor; review each resource in detail to establish standardized vocabulary, metadata and subject classification.
- Editorial reviewers: Specialists for this process related to the review of the OER; they cannot make changes to the metadata and content of the OER.

Some of the issues and challenges identified in the TEMOA case study are: problems throughout the chain of presentation of resources, such as errors in filling metadata at different stages of the chain; dispersion of the cataloguing staff across different states of the country, which poses challenges to synergistic work; and the lack of a clear strategy in the development of the portal, making it difficult to identify the target users and also the process of collection, development and organization of the information. Currently several measures are being proposed and studied within the developing team to solve these issues.

In Africa, several initiatives exist. OER Africa[61] is an initiative of Saide[62], "established in 2008 with support from the William and Flora Hewlett Foundation, to collaborate with higher education institutions in Africa in the development and use of Open Educational Resources (OER), to enhance teaching and learning." [63] TESSA (Teacher Education in Sub-Saharan Africa)[64] is a network of teachers and teacher educators stretching across Sub-Saharan Africa, co-ordinated by The Open University (UK). They share and develop a bank of OERs, linked to the school curriculum. Resources seem to be available in four languages: English, French, Arabic and Swahili. TESS India[65] offers resources in English and in Hindi.

Repositories of digital education resources

This sub-category includes platforms that host a collection of digital resources, including learning portals and databases of e-books that are not necessarily OERs. These platforms function primarily as portals or gateways on the Internet to digital education resources, rather than as LMSs. Some provide facilities such as search engines, chat, free downloads, links to related sites, and personalized content. For example, British Council's Learn English Online webpage offers free online resources to help adults, including business professionals, teenagers and children learn English. The

61 https://www.oerafrica.org/
62 Saide is a non-governmental organization conducting projects throughout South Africa and sub-Saharan Africa. See https://www.saide.org.za/#about
63 https://www.oerafrica.org/about-us
64 http://www.tessafrica.net/home
65 http://www.tess-india.edu.in/

resources include videos, mobile apps, games, stories, listening activities, grammar exercises and MOOCs in partnership with FutureLearn.

(3) Learning environments

For this category, the expert group sampled a number of MOOC platforms, LMSs and social network sites originating in different continents. With the advent of LMSs and MOOCs, it is not surprising that universities, companies, governments and civil society organizations are developing products and platforms that not only target traditional K-12 and post-secondary students but also appeal to the broad masses of adult learners as they populate their platforms with a broad range of topics (Tan and Lee 2018). Perhaps the largest curriculum-aligned K-12 online learning platform in the world is 17zuoye, which is China's largest K-12 platform based on the national curriculum with 60 million subscribed users (see **Box 3-3**). 17zuoye has established the largest real-name online teachers' forum in China, the largest WeChat parent's group, and a digital community of teachers, students and parents organized by classes (Zhang 2017). These communities connect teachers to teachers, students to students, and parents to parents, as well as creating cross-connections between groups.

Box 3-3 17zuoye: China's largest K-12 online learning platform (by Deng Chen and Russell Hazard)

17zuoye started small by offering customized homework solutions to the existing education system. Initially it was a tool for homework assistance but has since seen diversification of materials including digital online learning materials. The platform was founded in 2007, and by March 2019 it had over 60 million subscribed users of whom over 50 million were students from 140,000 schools in 365 cities across 31 provinces in China (17 Edtech Corporation 2019). It is the largest K-12 online learning platform in China and has recently raised $250 million in a series E funding rounds for further expansion (36Kr 2018).

17zuoye means 'doing homework together' in Chinese. Chinese children spend an average of two hours on homework every day (Harbinger 2017). The high cost of tutoring and a lack of differentiation in homework assignments have been widely criticized in the media in China. 17zuoye initially used this market context to grow by offering free online exercises and assessments for math and English that teachers can customize and assign to students in and outside class. 17zuoye then started providing teachers with free and easy-to-use teaching tools and automated statistics. It also started providing students with other online learning resources and more collaborative learning experiences in addition to personalized homework and assessment content. Parents can receive digital study reports so that they have immediate feedback on their children's progress.

Expansion in subjects and device choice

From its initial success in online homework and assessments in math and English, the company expanded to other subjects, namely, Chinese, physics, chemistry, biology, geography, politics and moral education (including ethics and citizenship) in both primary and secondary education. It also began to offer diversified digital resources and services such as live online tutoring services. Students can engage in self-directed learning using a variety of OERs. Teachers can exchange materials, prepare classes and have discussions in platform forums. Parents can locate resources and communicate directly with teachers and other parents. In 2018, the company began monetizing by offering what it calls the Socrates Smart Learning System to support more personalized and competency-based learning.

However, most of the resources on the platform are free except for the premium online tutoring courses and services (the premium services are individualized learning solutions including personal learning plans, content and courses).

All the resources have been made accessible across multiple devices and operating systems. The platform was initially purely desktop based. However, it is now also optimized for mobile use, and mobile device connections are expanding (Harbinger 2017). The premium interactive online learning, such as guided MOOCs and tutors use economy of scale and are relatively inexpensive (many under $2 USD). The company is currently developing Virtual Reality (VR) and Augmented Reality (AR) capacity.

Levering the national curriculum and big data analytics

The exercises and assessments on the platform are based on the latest curriculum implemented by China's National Ministry of Education. In the first quarter of 2016, the platform had more than 100 million core curriculum questions, and by 2017 it had more than 12 billion (Harbinger 2017). This focus on serving the national system with free-access support means that, as well as serving teachers and families directly, many schools and even districts adopt the platform in their day-to-day operations. Recent metrics show that even in 2017, 17zuoye was processing more than 5TB of user data every day (17 Edtech Corporation 2019). Using big data analytics, the platform continually learns about the students, their response patterns, the content and pedagogy, and utilizes this information to make improved recommendations about content choice, pace of learning and approach. The data, sorted by class and school, is also available to schools and teachers so they can have convenient and timely access to teaching feedback. Through online interactive communication, teachers can manage the learning situation in real time, from paying attention to subject knowledge to children's ability growth.

As the example of 17zuoye clearly shows, a platform can provide a number of services that make the resources interconnected and thereby less attractive outside the platform. The interaction with the student can be recorded, stored and processed, which in turn can be viewed by the teacher (via a dashboard) and the student. Calculated indicators for an entire class can also be provided to the teacher. They can be used by the teacher to give advice to students, analyze their mistakes, suggest other resources, or even allow automated progress management. The platform can possibly collect data on a large number of students, allowing more general analyses, using AI techniques in particular.

A central question is the place of the teacher in the management processes provided by such platforms. The teacher can control the platform by selecting the exercises or interpreting the analytics presented in order to choose what to do for the students. Some platforms allow teachers to create their own resources, link them to scenarios for students and benefit from student interaction management services. It is also possible that the teacher may be put aside at times, with the platform taking care of the interaction with the students and their progress. This may especially be the case if teachers are not trained to work with such platforms.

National governments have developed learning platforms, focusing on both a single subject and multiple subjects. For example, Luxembourg uses MathemaTIC, an adaptive mathematics learning platform for students in primary and secondary schools, developed by an EdTech company based in Canada. Students work through interactive mathematical items mapped to their curriculum and are provided with adaptive scaffolding to activate prior knowledge by using several learning

strategies, which lead to adaptive help-seeking. The MathemaTIC dashboards provide teachers with visualizations of the data gathered from students' activities using the mathematical items.

Nemzeti Köznevelési Portál (NKP, which means National Portal for Public Education) is Hungary's web-based education platform that covers multiple subjects and levels. The portal was developed by Hungarian Institute for Educational Research and Development (see **Box 3-4**). The resources comprise subjects such as Hungarian grammar and literature, mathematics, morality, ethics, music, drama and dance, visual culture, physical education and sports, chess, innovations from Year 1 till 12 and 12+. The themed, easily searchable and secure educational space helps teachers prepare for class, while for students learning at home is also facilitated through interactive exercises. NKP also makes textbooks freely available, stores information on how students solve tasks, and in the case of an incorrect answer directs them to relevant textbook content. Personal information of users is handled in compliance with the EU General Data Protection Regulation (GDPR), which means that statistics will only be used for the validation and improvement of the platform.

Box 3-4 National Portal for Public Education (Nemzeti Köznevelési Portál, NKP, Hungary) (by Gergely Pintér, Hungarian Institute for Educational Research and Development)

The National Portal for Public Education (Nemzeti Köznevelési Portál, NKP) is Hungary's foremost web-based education platform, developed by Hungarian Institute for Educational Research and Development to implement the Hungarian Digital Education Strategy. The Strategy, which is integral to the country's Digital Success Programme, was developed based on the recognition that digital transformation is an inevitable phenomenon that everyone must prepare for. It posits that digital tools and approaches should be introduced in the classrooms.

The platform provides teachers, students and parents nationwide with digital education resources, with the software designed for up to 1.2 million users including primary and secondary students, their parents and teachers. The whole infrastructure is in Hungary, and it is a scalable system that can expand when the demand arises. In other words, new servers can be added quickly to support more users, if necessary. Currently, in NKP textbooks in two versions (a PDF version and a HTML version, which is the smartbook with digital learning objects such as videos, exercises and 3D simulations) are available freely for all students between grades 5 and 12 (11 to18-year-old children). This can be a bridge between the regular paper-based and digitally-mediated educational methods. Currently the system does not support access to the portal contents and functions in offline mode.

NKP provides ready access not only to terabytes of textbooks, guides, exercises and digital supplements, but also to easy-to-use, free services for teachers and students. It is not just a collection of digital books but a complex e-learning system capable of helping the teacher to build private lesson plans, smart exercises, assignments, online tests and more. There are exercise editors for NKP. Thousands of verified interactive exercises, videos, 3D simulations, digital maps, and so on can support teachers to make their everyday lessons more exciting and attractive for their students. The themed, easily searchable and secure educational space helps teachers prepare for class, while for pupils learning-at-home is also facilitated through enclosed interactive exercises that signal back to students in various ways. The system contains a large number of pre-defined lesson plans, so that teachers can grab the most suitable tools for their needs, which they can also customize. A collection of 'best practices' is also available in the form of digital books on the platform, which can give the teachers guidelines.

NKP stores information on how students solve tasks, and in the case of an incorrect answer directs the user to relevant and helpful textbook content. To facilitate discovery and involvement-oriented, active learning, the NKP connects users through already existing and well-functioning portals and public collections of material. It provides a platform to teachers for the assessment of students' performance. Personal information of the users is handled as is defined by the GDPR. The usage statistics are only meant to be used in the validation and improvement of the portal.

The robust framework of the NKP aims to help students in learning more effectively and direct teachers towards more enjoyable classes with the help of AI and digital media. The latest version of digital textbooks or 'smartbooks' follow a particular educational guideline identified in advance, which is based on the contents of the NKP. The guidelines are created by the digital editors who are also teachers. Every book has an editorial staff that designs the layout and the additional learning objects of the smartbook. The smartbook contains several embedded learning objects, but the NKP system stores many more objects that are not directly in the book. These objects can be found in the search modules and can also be used in a class. This makes the two products (digital textbook and the NKP) inseparable.

Box 3-5 Machines with extraordinary educational powers: From scrambled books to learning management systems

Chapter 2 (section 3) introduced scrambled books. It is interesting to look at the discourse that accompanied these books, including the TutorText series developed by Crowder. Below are excerpts from the preface to a scrambled book published in 1958.

> *The presentation of the teaching of this book is as close as possible to a conversation between a tutor and his pupil. This book provides knowledge in small doses and verifies the reader's understanding through multiple choice questions; Questions that the reader must answer in order to go further. A wrong answer leads to a more thorough examination of the point at issue; A good answer leads to the next unit of information and the related question... (Crowder 1958)*

Further, the excerpt below paints an image of the scrambled book with amazing educational powers:

> *The book we are presenting here is intended to play the role of the preceptor. Just like a flesh tutor, he will show you the way, bring you the necessary knowledge, and constantly ask you questions to judge whether you have understood ... This book will record your answers, will give you some more explanations when you will need it and, as soon as he realizes that you have assimilated what he has taught you, you will take a new step. (Crowder 1958)*

After 60 years, the bold claim that amazing customization is enabled by a simple scrambled book with a fixed structure strikes us as rather strange. This preface is obviously trying to give the reader the illusion that a completely predetermined process ensures a dynamic follow-up like a human tutor. The particular organization of the book gives it a kind of intelligence. But today what about the discourses accompanying recent learning platforms? We find the pieces of information given little by little, a path followed that guarantees the acquisition of these pieces of knowledge, a machine that 'understands' what the learner has in mind, thanks to science. For example, below is how CENTURY characterizes itself:

> *With CENTURY, your students have a personalised learning path made up of micro-lessons called nuggets. CAI, our AI technology, understands how an individual learns best and is constantly adapting to provide the support or challenge each student requires. Teachers can choose to assign nuggets or let CENTURY do the work. (https://www.century.tech/the-platform/)*

Such a feature is made possible by recent research:

> *How does CENTURY recognise the needs of each student and know how best to support them? The answer lies in neuroscience. CENTURY incorporates research on how the brain learns and retains information to ensure each learner is individually supported. (https://www.century.tech/the-science-behind-century/)*

These two illustrative examples — one paper and the other digital — clearly show that the discourses accompanying them are essentially the same. In these discourses, learning is considered as an individual knowledge acquisition process, and technology can guarantee that one will learn more in less time. The underlying vision of learning is fundamentally the same whether the technology is analogue or digital.

(4) Digital tools for teachers for designing educational resources or for evaluation

Many resources have teachers as their primary targets. One such resource developed by a publishing group is One Stop English, a teaching resource site of Macmillan Education. It houses more than 9000 resources based on age, level and language focus, with audio and video lessons, games, songs and flashcards. It includes the Learning Calendar, a tool that enables users (subscribers) to organize resources, plan lessons and share links with colleagues and friends. Resources can be arranged into folders and scheduled into the calendar. The user can bookmark pages, groups of resources or individual resources, as well as add bookmarks to one's Learning Calendar for any other teaching resource or site on the web, directly from the Learning Calendar by clicking on the 'Add an internet bookmark' button. Bookmarks can be organized into folders to create groups of resources, according to level, age group or to individual classes taught.

In addition to commercial products, there are also many government initiatives for helping individual teachers. For example, in 2016, Estonia's Ministry of Education and Research launched the portal e-Koolikott. It allows easy access to digital learning materials and facilitates teachers to use materials from different websites, combine videos, games, worksheets and other educational tools, and make the created learning kits easily accessible for students and peers. These digital learning materials are arranged by keywords based on the curriculum. Educopédia, created by the Rio Municipal Department of Education in Brazil in 2010, is a platform of online digital classes for multiple subject areas. It offers resources to support teachers, lesson plans, pedagogical games and videos, and other tools. These resources were produced by 300 teachers of the municipal network, based on the curricular guidelines. It covers all disciplines, from Early Childhood Education to the 9th grade, as well as the PEJA (Youth and Adult Education Program). Each subject has 32 digital classes, which correspond to the weeks of the school year. The platform also provides training courses for teachers. **Box 3-6** presents a case of Brazil's Ministry of Education's OER platform for teachers.

Box 3-6 MEC RED: Brazil's OER Platform for teachers (by Ilana Souza Concilio)

In 2015, the Ministry of Education (MEC), in partnership with the Federal University of Santa Catarina (UFSC), Federal University of Paraná (UFPR) and teachers of Basic Education all over Brazil, developed the MEC RED – Plataforma MEC de Recursos Educacionais Digitais (Integrated Platform of Digital Educational Resources) (https://portalmec.c3sl.ufpr.br/home).

The MEC RED aims to use OERs to enrich basic education, bringing together video files, animations, games and other formats for use in schools (MEC 2018). It is a dynamic platform, with efficient search tools for easy manipulation by education professionals. It combines a digital content environment model with a social networking model. Users can search, download and browse 30,000 digital files. In addition, it is possible to store resources in personal or public collections, which assists teachers in the organization of their classes. It is also possible to indicate resources to colleagues by social networks, by e-mail and through the profiles on the platform.

The platform focuses on basic education teachers, but is also open to students and the community. Teachers can find material that fits their class objectives, share instructional experiences regarding the use of a particular resource in the daily school life, and suggest and learn new uses for the same resource. Since its launch in 2015, 29,423 digital files and more than 23,000 searches have been stored on the platform. Access was also recorded from 41 countries, in addition to Brazil, such as the United States and Portugal (MEC 2018).

According to the MEC (2017), the MEC RED platform has the following characteristics.

- Space built by and for teachers: The platform constantly seeks to understand the reality of teachers inside and outside the classroom in order to adapt its quality to their search needs for digital educational resources.
- Collaboration environment: The platform is a space where teachers can collaborate by sharing and also publishing. In addition, they can contribute by reporting experiences of their use of the available resources.
- All features in one place: The user can optimize time as the platform integrates digital educational resources of the major open portals.
- Partner portals: The user can find on the platform digital educational resources of various partners, and the platform marketers can suggest content from other sites.

Another interesting type of resource is a product developed by a company for a government agency for student assessment. In 2015, the Division of Evaluation, Planning and Performance (DEPP) at the French Ministry of Education partnered with Vretta to develop the large-scale, interactive assessment platform, DTab, to assess the performance of primary-school students in an offline, mobile environment. This corresponds to the strategic vision of the DEPP to mainstream large-scale digital assessments for all primary-school students across France. According to a member of DEPP, DTab also functions as an online interface for DEPP to create and manage evaluation items ('item builder'). Vretta is the service provider for the creation of mobile applications for offline assessments of primary-school students on digital tablets. For middle and high-school students, the evaluations are carried out online by DEPP with the CAT platform[66]. DEPP is also collaborating with the Luxembourg Ministry of Education on an adaptive mathematics-learning platform called MathemaTIC[67], also developed by Vretta, briefly described in Category (3).

66 See https://www.taotesting.com/
67 https://www.mathematic.lu/

(5) Resources by opportunity and open data for education

In addition to resources designed explicitly for educational purposes, is a category that may be called 'educational resources by opportunity', that is, resources not initially designed for use in a teaching context but which teachers may decide to use for educational purposes. For example, high quality digital resources produced by museums of arts, natural history, science as well as by companies and mass media (audio-visual archives, for example) can play an important role in both formal and non-formal education settings. The question is how to make such resources available to teachers and students. Either producers grant them a free license by making OERs of their resources, or it is necessary to negotiate rights of use in education. **Box 3-7** gives an example of the Eduthèque, directly funded by the French Ministry of Education to enable free use of these resources by teachers and their students.

Box 3-7 Éduthèque: Educational, cultural and scientific resources for teachers and their students

Éduthèque[68] is a web portal created by the French Ministry of Education. It is free for all teachers and their students, at both primary and secondary school level. Based on a partnership with major cultural and scientific public institutions, Éduthèque gathers the partners' resources.

More than 80,000 digital educational resources are available on the portal, such as videos, movies, 3D models, documentaries and maps. These resources, of high scientific quality, are downloadable, their rights are cleared for educational purposes, and they are also accessible to people with disabilities and special needs.

The web portal allows users to discover each offer one by one. Teachers and students can also use the meta-search engine through which they can access a specific resource and discover others. Thus, by varying the entries and exploring the documents of the different partners, teachers can meet diverse needs of their students.

Teachers benefit from the pedagogical support offered by Éduthèque. The portal is easy to use, free for teachers and their students, and without advertisements. The news section offers thematic selections of resources relevant to the educational program. Partners also provide useful lesson plans and activity tips for teachers and their students. Teachers can also find interesting learning aids for citizenship education, literature, arts and cultural education, media and information education.

Yet another component of the category of resources not sampled by the expert group is data on education. Advancements in digital technology have improved the efficiency of information collection and management. Education Management Information System (EMIS) is a good example. EMIS can be defined as "a system for the collection, integration, processing, maintenance and dissemination of data and information to support decision-making, policy-analysis and formulation, planning, monitoring and management at all levels of an education system" (UNESCO 2008b, p. 101). The idea of EMIS has been around since the 1990s, and although the development of EMISs has been uneven across the world, the internet-based (sometime intranet-based) EMIS, accessible through a portal website of the concerned Ministry of Education, has become the norm. EMIS is available as OpenEMIS, a generic and open source EMIS software package.[69] In April 2018,

68 https://www.edutheque.fr/accueil.html
69 https://www.openemis.org/

UNESCO and the Global Partnership for Education (GPE) organized an international conference to support countries maximize EMISs towards achieving SDG 4 on quality education.[70]

According to a recently published working paper on AI in education by UNESCO (2019b, p.15), countries are interested in "transforming their current EMIS from a school-based aggregated administrative data management system into an integrated and dynamic learning management systems [sic] that can effectively support real-time decision-making in every aspect of education sector management". The Beijing Consensus on Artificial Intelligence and Education (UNESCO 2019c, paragraph 10) recommends governments and other stakeholders to "consider integrating or developing AI technologies and tools that are relevant for upgrading education management information systems (EMIS) in order to enhance data collection and processing, making education management and provision more equitable, inclusive, open and personalized".

Many international data stakeholders, including UNESCO through its Institute of Statistics (UIL)[71], the World Bank[72], and the African Development Bank[73] use data from EMISs to monitor progress towards achieving educational development goals. These international organizations as well as many national educational systems, for example, in Australia[74], France[75], India[76], Norway[77], United States[78], Northern Ireland, Germany, and Switzerland[79], provide 'open' data. According to the Open Data Handbook[80], "Open data is data that can be freely used, re-used and redistributed by anyone—subject only, at most, to the requirement to attribute and share alike." This implies that the data must be available, accessible and easily editable. A key point is interoperability, "the ability of diverse systems and organizations to work together (inter-operate)", allowing the intermix of different datasets (ibid).

Of course, open data is not only about education and can concern many different domains. Using such data can offer productive educational situations. Also, in the open data idea, 'non-commercial' restrictions that would prevent 'commercial' use, or restrictions of use for certain purposes (e.g., only in education), are not allowed. Combining different datasets can facilitate developing more and better products and services. EdTech companies can benefit from open data in designing offers for education.

However, having access to a large quantity of products, regardless of their quality, does not guarantee learning for students. It all depends on the contexts and situations in which the products will be used and the learning dynamics that will be developed. This raises the question of the place of school-based tools and more particularly textbooks.

70 https://en.unesco.org/news/unesco-gpe-launch-first-international-conference-education-management-information-systems-0
71 Data on SDGs are downloadable from http://data.uis.unesco.org/
72 The World Bank provides a portal giving access to data about education across many countries https://data.worldbank.org/topic/education
73 The African Development Bank provides information on the development and implementation of SDGs http://sdg.opendataforafrica.org/?lang=en
74 https://www.ands.org.au/working-with-data/publishing-and-reusing-data/data-in-education, https://bond.libguides.com/statistics-open-data-sets and https://data.sa.gov.au/data/dataset
75 https://data.education.gouv.fr/pages/accueil/
76 https://data.gov.in/sector/education
77 http://data.norge.no/
78 https://www.data.gov/education/
79 Education: Open Data in Schools https://www.europeandataportal.eu/en/highlights/open-data-schools
80 http://opendatahandbook.org/guide/en/what-is-open-data/

3. Rethinking the Role of Digital Textbooks

What really matters is how teachers and students use paper and digital resources, in ways that meet their unique needs

This chapter has shown that the digital textbook is, above all, a cultural and economic object. Most digital textbooks have not yet been transformed much from traditional models by technology. The production of a digital textbook, its extensions, its mode of reading or circulation have been transformed, but it typically retains a traditional form. The textbook is a tool at the heart of the school tradition, and its digital permutation reflects this. Even if it inherits many characteristics from other digital objects, it remains close to the paper version. It can be an object (a physical medium), an open object, content on a platform or even a service. It can include all the functions of traditional books (manual, workbook, glossary, exercises, etc.). In contrast, there are no constraints and no limits on digital education media, designed for education or simply used in education, and there is a great deal of diversity in digital education resources in circulation today.

The world of print publishing and the world of digital development are still far apart. On the one hand, school publishers in many countries are confronted with approval processes and readability tests, while computer products undergo ergonomic studies or user experience analyses. Even in the absence of regulation of textbooks, as in the case of countries that abolished textbook approval protocols[81], school publishers must acquire new skills. For example, editing and production processes of educational resources have to take into account accessibility and indexing issues, but these transformations may be difficult because they sometimes challenge the established positions of school publishers (Levoin 2018).

In *Literature Review Digital Textbooks,* Blazer (2013) underlines the advantages of digital textbooks as including "up-to-date content, multimedia features designed to enhance learning, 24/7 availability, and the ability to better engage tech-savvy students." This literature review also mentions the classical argument of reducing students' backpack load. In response to this problem of schoolbag weight recalled by newspapers at the beginning of each school year,[82] some publishers have implemented alternative solutions such as splitting textbooks in two parts, one part staying at home, the other part at school. On the negative side, in addition to the possible inconsistency of the quality of content in digital textbooks due to the less rigorous or non-existent vetting process, the literature review notes that "digital textbooks may not be conducive to in-depth reading and that their interactive features may interfere with students' content retention".

Both the advantages and disadvantage highlighted here are related to *features* of digital textbooks rather than questions of *use*. However, not only does digital technology offer new functionalities, it also makes it possible to review the very processes of textbook production, rethink the production chains, and get remote teacher collectives to work together. Digital technology makes it easier and more localizable to publish paper textbooks, and what really matters is how teachers and students use paper and digital resources, in ways that meet their unique needs.

As we have seen, supporters of the École Nouvelle such as Freinet (see **Box 2-3** in Chapter 2) in the early 20th century were very critical of textbooks. Textbooks were considered closed, presenting

81 See the international information platform edu.data of Georg Eckert Institute http://edu-data.edumeres.net/en/. It provides information on textbook systems worldwide.

82 For example, in 2002, in the lower secondary school of Moreuil (France, near Amiens), where the Vivendi digital schoolbag was experimented with, its arrival gave the opportunity to organize a communication show. The Korean TV was present, and on the website several pictures and videos celebrated the event. One photograph showed two students comparing the weight of the digital schoolbag with some textbooks: "On one pan of the balance, the digital schoolbag, on the other: the dictionary, the history book... The science book does not lie and the pan already leans..." (Bruillard 2003).

only one method, leading to "enslave the child's thinking" (Freinet 1928). In order to open up the world to students, the idea was to give them access to many other resources of all kinds, and that they should be able to build their own textbooks. The context has changed significantly since the times of progressive educators and school reformers of the early 20th century such as Dewey (1859 – 1952) and Freinet (1896-1966). Since the middle of the 20th century, many textbooks have tried to introduce forms of differentiated pedagogy, which has sometimes made textbooks difficult to read in a linear fashion.

Gradually, we moved from a situation where educational resources were scarce to a situation of abundance, a phenomenon that has accelerated with the deployment of the Internet. However, accessible quality resources remain unevenly distributed. The issue of resource selection also becomes crucial in the current environment, and the availability of a multitude of unorganized resources can even become a barrier to successful learning. Textbooks and digital textbooks can be of key importance because they have several essential characteristics: most, if not all, textbooks are based on systematized subject-matter knowledge and pedagogical knowledge—what Schulman (1986) called pedagogical content knowledge (see **Figure 1-1**)—which is compatible with the organization of the school system and can be implemented easily by teachers.

Are textbooks obsolete? asked Bill and Melinda Gates in their 2019 Annual Letter.[83] Their answer is positive as "software is finally changing how students learn". Nevertheless, when new technologies appear, the oldest ones rarely disappear: they coexist, hybridize, in complex comings and goings. More than a hundred years ago, Thomas Edison predicted that motion pictures would make the use of books in schools obsolete.[84] Television has not replaced cinema, the Internet does not replace television or cinema, but the programs offered are renewed. The model of textbooks may be obsolete, but not the idea of textbooks. Perhaps it is a question of rethinking the role and structure of textbooks, given the multiple digital resources available, in this new context of abundance.

As we have seen, textbooks can be enriched or augmented, they can offer links to external resources, integrate teachers' personal resources, provide different paths and facilitate differentiated pedagogy. In an era characterized by a shift from closed-ness to openness and selection, a key role of textbooks — a hybrid of digital and paper — can be to offer structure for core content and to act as an organizer of a pool of external resources. It should also be noted that textbooks were once produced in large numbers centrally, making it difficult to update them. They were supplemented by what students wrote on their notebooks and by photocopies distributed by the teacher. Nowadays, textbooks can be designed by remote teams and distributed digitally. They can be printed locally, in part or in whole, integrating notes on notebooks and allowing adaptations to the local context. This contributes to ensuring a form of personalized learning that is culturally and locally contextualized and connected to national and global realities in a meaningful way. **Box 3-8** describes examples of textbooks collectively produced by teachers and locally completed in schools in Italy.

The model of textbooks may be obsolete, but not the idea of textbooks. Perhaps it is a question of rethinking the role and structure of textbooks, given the multiple digital resources available, in this new context of abundance.

83 https://www.gatesnotes.com/2019-Annual-Letter

84 Thomas Edison's famous quotations on textbooks have gone through several iterations. See https://quoteinvestigator.com/2012/02/15/books-obsolete/

Box 3-8 Self-production of textbooks in Italy (by Alessandra Anichini)

Avanguardie Educative is a network of Italian schools, promoted and supported since 2014 by INDIRE, a national institute for educational research. Its purpose is to rethink the Italian school model, still strongly classroom-lecture-activity-based and constrained in its rigid organization of time-schedule. **CDD/Libri di testo** (where CDD is for Contenuti Didattici Digitali or Didactic Digital Content) is one of the innovative ideas promoted by **Avanguardie Educative**, assuming that publisher textbooks play the role of a hidden curriculum, contributing to a strong persistence of the lecture-centred model of schooling. The network involved teachers in a reflective process to help them not only master procedures and practical advice for other schools, but also develop a deep understanding of pedagogical issues behind the practice. This led to a document called **Avanguardie Educative CDD-Textbooks Guidelines,** which argues that the textbook has to be a 'canvas' that guides class activity and has to be populated by contents bound to the particular context of the school. The kind of textbook prefigured by **the Guidelines** is like an '**unfinished book**' or an '**open book**', very close to a good example of a digital one.

In Italy, teacher practices related to adoption of textbooks can be grouped into the following three major categories.

1. Adoption of textbooks produced by teachers. The most important model is the 'Book in Progress' initiative promoted by ITI Majorana of Brindisi[85], which for years has been coordinating and promoting the activity of a large group of teachers committed to the production of teaching manuals to adopt in their own classrooms. The activity of the network is spread throughout the country. The motivation behind the rejection of books offered by school publishers lies in the evaluation of the texts themselves, often considered inadequate for students' needs, far from the context of school life and too expensive.
2. Adoption of digital teaching resources produced by teachers and students. This has been carried out by an institute in the province of Piacenza, which has launched the proposal of adopting digital resources self-produced by teachers in collaboration with students, limited to certain curriculum disciplines (only music and geography for the first year of the project, plus Italian for the second), to contain the spending ceiling in accordance with the law. (The Libr@ project of IC Cadeo and Pontenure is the reference model)[86].
3. Self-production of integrative digital content. Many schools, while retaining the textbooks of traditional publishers, also produce digital content with the class regarding particular aspects of the curriculum (disciplinary or interdisciplinary). This kind of activity is now widespread in many schools, carried out by individual teachers, almost 'handcrafted', rather than being a system activity provided by the school curriculum.

Instructional and pedagogical implications

In the schools that are developing their own textbooks, studying concerns something different from the faithful repetition of what is written in the textbook. It means first 'rewriting knowledge', an active investment by every student within a working community represented by the class. Designing and producing the 'pages' of a textbook means that students are approaching a range of skills that involve information retrieval, understanding and interpretation of collected data, formulation of hypotheses and concepts, and their formalization and representation in a form

85 http://www.bookinprogress.org/
86 http://www.istitutocomprensivocadeo.it/progetti/progetti-tecnologici/progetto-libr

considered to be more appropriate to their communication. It also means experimenting with new forms of writing according to the tools offered by digital support, while still integrating paper support, which is very useful especially for the opportunities it offers for elaborating and creating content. Students can also reflect on the main features of digital texts and on a new kind of writing.

The production of digital content (or textbook) represents the opportunity to re-adjust the curriculum according to specific needs of a particular context, which is to adapt the national curriculum to the 'emerging curriculum', the latter being deeply bound to the demands and characteristics of the school and the student. It allows addressing the marginal themes of the curriculum, for example, the local history curriculum and topics that are not present in traditional history textbooks. It allows students to express their ideas about their reality, and to re-establish a more authentic relationship with their world.

Before concluding this chapter, three points deserve to be highlighted. The first concerns the tension between two possible models. On the one hand is an emerging set of largely independent resources and the possibility to curate a catalogue of resources. On the other hand, the book model is retained as a unit with the same thought behind it. For school publishers, maintaining the book model — structured, organized, linear and progressive — is essential for students so that they can have stable reference points. If abundant learning opportunities can be harnessed through the Internet, the question arises of how to structure these offerings and how to mediate them. Teachers may find a combination of these two models preferable (a digital textbook and a set of tools and educational media).

Second, as the tools associated with textbooks and electronic resources develop, how can we ensure that teachers in particular master this instrumentation? Are they to be consumers of resources produced by others, simple local modifiers or adapters? Or will they become producers within regional or national disciplinary collectives, supporters or instigators of more profound changes? What roles will they play in a school where computerization in its various forms has taken an important place? These are essential questions, though still open ones.

Third, subscribing to the simplistic dichotomy between paper and digital is not productive to say the least, as paper and digital are intertwined and complementary. Printing or scanning a document makes it relatively easy to switch between digital and paper. Whereas there is much interest in 'going digital' in education, the idea of 'fully digital' education runs the risk of impoverishing learning experience because it privileges the senses of hearing and sight over the other senses. Going paperless is not necessarily a good solution, since paper still has many advantages, providing good environments for reading and writing. It is important not to limit education to digital, as human beings have corporeal bodies — that is, physical forms in the material world — and a range of basic requirements to live a meaningful and fulfilling life.

CHAPTER 4

Exploring the Pedagogical Possibilities of Digital Resources

Following Chapter 3, which has provided snapshots of digital products already in circulation, Chapter 4 looks at pedagogy enabled or facilitated by digital technology. The goal is three-fold. First, the chapter introduces promising examples of the use of digital technology in education, with a special focus on 'cognitive' or 'intelligent' computer tutors. Second, the chapter puts into perspective the visions and theories of learning underpinning what are often uncritically espoused as 'learning solutions' and 'learning innovations'. The implications of championing different visions of learning are discussed both in relation to (1) new discourses around personalized learning, AI and big data and (2) the normative vision of education for sustainable development and global citizenship. This will help us better envision and develop pedagogy and educational practices supported by digital technology.

Third, the chapter presents a model which helps us explore the pedagogical possibilities of digital education resources broadly defined, including e-textbooks, OERs, intelligent tutors, simulations, games, online courses and collaborative workspaces. All too often, theorising is far removed from practice on the ground. This demands intermediate knowledge that can bridge the gap between theory and the messy realities of everyday practice in schools, classrooms and informal learning environments. We present a heuristic model to illustrate pedagogical opportunities opened up by digital technology — conceptualized as the possibilities afforded by the digital or 'affordances'. Based on a review of various writings on the use of digital technology in education, we identified eight affordances such as ubiquitous learning, active knowledge making, multimodal meaning, and recursive feedback. The chapter concludes by briefly outlining the potentials and limitations of the eight affordances (8A) framework.

1. Improving learning with technology: Examples of student learning gains

Our current fascination with digital education is still largely based on perceptions of its promise, rather than evidence of its efficacy.

There are many studies reporting that the use of ICT in the classroom enables active learning and student engagement, increases student motivation to learn, and augments student satisfaction (see Vorvoreanu 2014). However, evidence of student learning gains is rather limited, as we will see below. While the field of EdTech tends to talk about 'learning' rather than education, strikingly little is known about the relationships between technology use and learning (Holmes et al. 2018; Castañeda and Selwyn 2018; Pane 2018). Our current fascination with digital education is still largely based on perceptions of its promise, rather than evidence of its efficacy.

Writing more than 30 years ago, the prominent historian of education at Stanford University, Larry Cuban, characterized as follows the three promises implied in a succession of new technologies that had caught educators' attention since the 1920s, such as film, radio, tape recorders, television and computers:

- individualized instruction,
- relief of the tedium of repetitive activities, and
- presentation of content beyond what was available to a classroom teacher (Cuban 1986, p.4).

After more than three decades, these three categories still capture most of the benefits that we expect to derive from digital learning, nowadays typically characterised as: (a) 'personalized learning' and possibilities of customization; (b) digitization of what are perceived (by teachers) as tedious tasks, or tasks that could be performed better by machine learning algorithms; and (c) immersive learning, encompassing gaming and 'virtual', 'augmented' and 'mixed' reality. For example, recently-developed learning management systems such as CENTURY[87] in the U.K. (see **Box 3-5**) and Summit Learning[88] in the U.S. emphasize the promises of personalized learning and reduced teacher workload.

Although recent public and policymaking attention attracted by AI gives the impression that the promise of individualized learning is new, very similar ideas — of developing unique courses of study and instructional strategies for each student — enjoyed considerable vogue in the 1970s. While most educators subsequently concluded that such approaches were unpractical given the state of technology then, as technology has advanced, some evidence has emerged of computer tutors providing individualized instruction that 'works' in terms of student learning gains. One widely-cited example is Carnegie Mellon University's 'Cognitive Tutor' program, an instructional system that supports guided learning-by-doing,[89] especially in the form of the Cognitive Tutor Algebra course (Koedinger et al. 1987; Ritter et al. 2007).

This course, originally created in the early 1990s, has been continuously tested in a large number of classes: increasing from 75 schools in 1998-99 to over 1,400 schools by 2003. It was selected in 2004 by the U.S. Department of Education for its "What Works Clearinghouse".[90] This software has been sold to many schools, as researchers collect further data and continually fine-tune the program. According to Koedinger, research tells more about the teaching and learning processes

87 https://www.century.tech/
88 https://www.summitlearning.org/
89 See PACT centre: http://pact.cs.cmu.edu/
90 https://files.eric.ed.gov/fulltext/ED539061.pdf

— what works, and what doesn't, when it comes to teaching students to correctly master algebraic formulae.[91] In this case, success in these terms results from long-range data collection and analysis of student work, in a discipline (mathematics, and specifically algebra) where 'correct' solutions are readily identifiable, and the pedagogical goal is thus clearly (and narrowly) defined.

While the Cognitive Algebra Tutor is one example of what has been technologically possible for about three decades, and indeed is already implemented in schools, another area of AI application in education involves computer tutors capable of conducting a 'mixed initiative' dialogue with students. This means that the machine can ask questions to the student but also answer the student's questions. VanLehn (2011) conducted a review of experiments comparing the effectiveness of human tutoring, computer tutoring, and no tutoring, and concluded that intelligent tutoring systems were nearly as effective as human tutoring.

AutoTutor is one example of this approach. It has been developed by the Tutoring Research Group at the University of Memphis, initially for supporting instruction in Newtonian qualitative physics and computer literacy. Its design was inspired by explanation-based constructivist theories of learning, intelligent tutoring systems that adaptively respond to student knowledge, and empirical research on dialogue patterns in tutorial discourse. AutoTutor simulates the discourse patterns and pedagogical strategies of a typical human tutor (Graesser et al. 2001), providing feedback, asking for more information, giving hints, identifying and correcting erroneous ideas, answering the student's questions, and summarizing answers (Graesser et al. 2004). Experiments showed that AutoTutor can produce learning gains across multiple domains (e.g., computer literacy, physics, critical thinking) (Nye et al. 2014). A recent extension of AutoTutor combined vicarious learning with interactive tutoring using trialogs: the human student is situated in a three-party conversation between a second agent student and a teacher agent (Graesser 2016). Over a dozen systems have evolved from the original AutoTutor.[92]

While these are promising examples, they seem to be closely linked to traditional subject teaching and individual knowledge acquisition, and have little, if anything, to do with promotion of the participatory and collaborative learning conducive to fostering the kinds of competencies needed in our time of turmoil and transformation. The next section therefore puts into perspective the visions and theories of learning underpinning what are heralded as 'digital learning solutions'.

2. Learning Sciences, Learning Theories and Visions of Learning

2.1 Learning sciences to produce 'evidence' of the instructional effectiveness of digital resources

With the aspiration of advancing the scientific understanding of learning, the field of 'learning sciences' has evolved since the late 1980s, integrating new developments in cognitive science, computer science, educational psychology, and other areas. The International Society of the Learning Sciences is dedicated to "the interdisciplinary empirical investigation of learning as it exists in real-world settings and to how learning may be facilitated both with and without technology", encompassing work conducted by researchers from diverse disciplines including "cognitive

91 https://www.businessinsider.fr/us/cognitive-models-and-computer-tutors-2014-3
92 See https://sites.google.com/site/autotutormem/ and the new website http://ace.autotutor.org/IISAutotutor/index.html

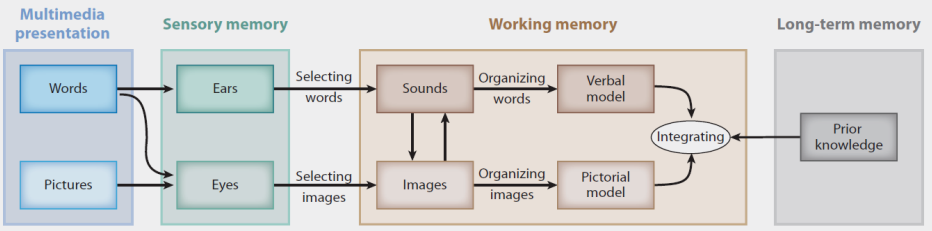
science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, instructional design, and other fields."[93]

Given the challenging economic climate in recent years, governments as well as funders of educational interventions increasingly demand reassurance of positive and cost-effective outcomes. Proponents of new interventions are required to demonstrate that their proposals are 'evidence-based'. This has given a further boost to the popularity of approaches to 'learning science' based on experimental methods. To give layman readers an idea of the kind of research design this involves, in the specific field of cognitive psychology, **Box 4-1** summarizes the findings of Richard Mayer's (2019) recent review of cognitive psychological studies on the instructional effectiveness of digital products.

Box 4-1 Mayer's (2019) review of experimental studies of instructional effectiveness of computer games

There are different visions of learning that guide research designs. Richard Mayer (2019, p.533) posits that "[stimulating] learning in ways that promote transfer is a fundamental mission of most educational enterprises." Here "transfer" refers to the application of what was learned in one context to another learning context. In such a vision of education and learning, knowledge, skills and attitudes are possessed by individuals and thus can be reasonably assessed through tests. **Figure 4-1** below presents the cognitive model of multimedia learning by Mayer.

Figure 4-1 Cognitive model of multimedia learning: the cognitive processes and mental representations involved in multimedia learning.



Source: Adopted from Mayer 2019, p.534.

Conducting a review of experimental studies of the instructional effectiveness of computer games, Mayer (2019, p.536, Table 1) identified three types of scientific research: (1) value-added research (Does adding feature X to a game cause improvements in learning?); (2) cognitive consequences research (Does playing game X cause improvements in skill Y?); and (3) media comparison research (Do people learn academic material better with a game or with conventional media?).

To date, the 'scientific' findings that can be derived from these three approaches are rather limited. Mayer's review concludes that:

i. in terms of value-added research, realism (e.g., immersive virtual reality vs desktop rendering), collaboration (i.e., playing in dyads or groups vs playing individually), and narrative theme (i.e., playing a game that has a strong story line vs playing one that does not) do *not* appear to be game features associated with greatly improving learning outcomes (p.538);

93 https://www.isls.org/

ii. in terms of cognitive consequences research, there is "little evidence that game playing improves cognitive skills besides a couple of promising effects … (i.e., first-person shooter games improve perceptual attention skills and Tetris improves two-dimensional mental rotation skill), and a potentially important effect in which specially designed games that focus on a specific executive function skill may be effective" (p.542); and

iii. in terms of media comparison research, there is no evidence "that games are generally inferior to traditional instruction" while there is "some reason to suspect that games can be as effective or more effective than traditional instruction for certain instructional domains and objectives" (p.544).

The third type of research included in Mayer's review, namely media comparison research, is an old field which predates the rise of digital technology and has explored if people learn academic material better with new media or with conventional media. What constitutes 'new' media has changed over time, but at times these studies have been criticized as confusing instructional methods with the delivery medium. Comparing outcomes of a face-to-face course to a MOOC, for example, does not tell us anything about activities carried out by the teacher or students in a face-to-face class or online. Any instructional environment — analogue, digital or hybrid — can support a variety of instructional methods and pedagogies, some better than others. For the critics of media comparison studies, it is misleading to commend or denounce the delivery medium for student outcomes as it ignores the question of instructional design choices (Lockee, Moore and Burton 2001). A report on the instructional effectiveness of online learning released in 2010 by the U.S. Department of Education offers a good case in point. This report provided a meta-analysis and narrative review of experimental and quasi-experimental studies focused on online learning in K-12 schools and higher education from 1996 to 2008 (Means et al. 2010). According to this review, online learning gave better but modest outcomes than face-to-face instruction, and adding blended elements (either to online or face-to-face) provided better results than entirely face-to-face teaching. As noted by the authors, however, blended conditions often included additional learning time as well as instructional elements not received by students in control conditions. It is therefore reasonable to attribute learning gains through blended learning not to the particular delivery vehicles of instruction but simply to more learning opportunities provided in blended learning courses.

Any instructional environment — analogue, digital or hybrid — can support a variety of instructional methods and pedagogies, some better than others. For the critics of media comparison studies, it is misleading to commend or denounce the delivery medium for student outcomes as it ignores the question of instructional design choices

Means et al. (2010) also noted two important limitations of the review, namely (1) the small number of rigorous published studies and (2) many studies carried out in settings other than K-12 education such as medical training and higher education, leading to caution as to any generalization about the effectiveness of online learning. After a decade since this review was conducted, these limitations are increasing becoming the things of the past. Given the rise of online learning in general and MOOCs in particular, large-scale studies with robust designs have become possible, resulting in new insights into the negative equity implications of online learning, to be discussed in Section 2.4 in this chapter (also see Bettinger and Loeb 2017, in Chapter 1).

Partly owing to advancements in functional magnetic resonance imaging (fMRI) technology, enabling scientists to view images of brain activity, neuroscience has gained increasing prominence over

the last two decades. As **Figure 4.1** shows, in Mayer's (2019) cognitive model of multimedia learning, learning is understood as cognitive information processing internal to individuals. Those who take a cognitive psychological approach and conduct experiments with a control group and an experimental group are often driven by the passion to demonstrate the effectiveness of a certain technology, product or feature through experiments, thereby building an evidence base for its adoption. This echoes the "scientific credibility" stage of Larry Cuban's (1986) conceptualization of an education reform cycle, consisting of the four stages: "exhilaration/scientific-credibility/disappointment/teacher-bashing". At this second stage of the cycle, "academic studies to demonstrate the effectiveness of the particular teacher aid as compared to conventional instruction" (ibid. p.5) are conducted, following the initial "exhilaration stage" which sees "claims predicting extraordinary changes in teacher practice and student learning" (ibid. p.4).[94] With regard to the use of games (and digital technology in general) in education, we are still at the "exhilaration" and "scientific-credibility" stages. Whether this leads to disappointment or 'transformative change' as often promised by digital education advocates remains to be seen.

When researchers conducting experimental studies are interested in finding out 'what works' and explaining it in terms of neural information processing, typically they neither ask if teachers really need or want the new technology in the first place, nor inquire whether teachers will have good equipment available and be trained to use it appropriately. Pedagogy is hypothesized as *embedded in educational software design*, and practice as the unproblematic application of theory.

When researchers conducting experimental studies are interested in finding out 'what works' and explaining it in terms of neural information processing, typically they neither ask if teachers really need or want the new technology in the first place, nor inquire whether teachers will have good equipment available and be trained to use it appropriately. Pedagogy is hypothesized as embedded in educational software design, and practice as the unproblematic application of theory.

In most cases, however, implementation is not as simple as applying what has been proven to 'work' in one context to another context. The difficulty of implementing 'evidence-based' practice is widely acknowledged in health care, as reflected in the development and uptake of 'implementation science' — the study of methods to promote the adoption and integration of evidence-based practices, interventions and policies into routine settings (Glasgow and Emmons 2007; Rabin et al. 2010; Scheirer 2013). In public health and medicine, 'implementation science' has been adopted to bridge the gap between theory and effective practice. By contrast, although cognitive psychological studies of the instructional effectiveness of digital products are analogous to studies of the effectiveness of new medicines or health interventions, implementation science is yet to take root in the education sector (Lyon et al. 2018; Moir 2018). **Box 4-2** briefly discusses some of the reasons why it is difficult to design and implement 'evidence-based' education programmes, and the barriers to transferring 'implementation science' from a sector such as health to education. The issue of implementation will be further discussed in Chapter 5.

Further, Chaptal (2009) argues that the question of effectiveness of the use of technology in education is generally misunderstood for three sets of reasons:

1. It draws upon an implicitly or explicitly 'productivist' approach (which focuses on making learning more "productive" and treats learning outcomes as 'products') based solely on measurable comparisons;
2. It is based on the illusion of the possibility of isolating a single variable, in this case ICT, whereas we are dealing with phenomena of extreme complexity where many factors interfere; and

94 In his seminal work *Teachers and Machines*, Larry Cuban (1986) vividly described the "exhilaration/scientific-credibility/ disappointment/teacher-bashing cycle" which "drew its energy from an unswerving, insistent impulse on the part of nonteachers to change classroom practice" (pp. 5-6).

3. It illustrates the paradox of assessing the supposed effectiveness of novelty by comparing it with indicators consistent with traditional models.

There are divergent ideas and competing viewpoints about learning with technology, and discussing them systematically goes far beyond the scope of this chapter. To highlight the limitations of a view of pedagogy as embedded in software design, the next section focuses on one approach which has recently captured the attention of policymakers, EdTech researchers and educators: 'personalized learning'.

Box 4-2 Difficulties in designing and implementing 'evidence-based' education programmes and promoting 'implementation science' in education

Although education and health sectors are similar in that they carry out preventive and therapeutic measures to achieve specific outcomes, the outcome measure for cognitive science — learning — is not as straightforward as that for health interventions. Compared to, say, what a blood test can reveal about the state of the body, learning assessments — however sophisticated they may be — can produce only rough approximations of the state of the mind (Chabbott 2007). While recent advancements in neuroscience have made it possible to reveal more about the state of the brain, we should beware of conflating the brain with the mind (Joldersma 2017). Given the difficulty of designing discrete interventions tied to straightforward outcome measures, many promising education innovations continue to lack a clear 'evidence base'. At the same time, many ostensibly 'evidence-based' programmes have proved difficult or impossible to implement effectively due to various problems, including fidelity (the extent to which the implementing teachers stick to the intervention manual) (see Humphrey 2013 for discussion of implementation of Social and Emotional Learning interventions). It is often not feasible for schools to recruit new staff to support implementation of an innovative new programme, with the result that innovations often overburden teachers already struggling with an overcrowded curriculum.

Moreover, few would contest that the outcomes to be desired from education are far broader than job-ready 'skills,' and should include the inculcation of values and capabilities conducive to fostering well-being for all, as captured in SDG 4 (see **Box 1-1**). Education is a long-term process involving far more than individual skills acquisition. It is therefore not realistic to expect consensus on 'objective' measures of the wide range of 'outcomes' associated with a holistic vision of learning, such as that put forward in the 1996 Delors Report (International Commission on Education for the Twenty-first Century 1996) — learning to know, learning to do, learning to be, and learning to live together. This challenge has most recently been reflected in the difficulty of defining the indicators of SDG 4.7 (see, for example, UNESCO MGIEP 2017).

Another consideration is the current economic climate, which exerts pressure on many organizations, including schools, to embrace rapid change while demonstrating 'effectiveness'. In reality, it can take many years before initiatives are integrated into everyday schooling and classroom practice. Writing on a study of the effectiveness of cooperative learning as implemented in secondary schools, Topping et al. (2011) conclude that the time required to fully embed the intervention into routine practice may call its cost-effectiveness into question. One barrier to the application of 'implementation science' is thus the failure to take into account the overall, long-term cost-effectiveness of mainstreaming the targeted practice (Morin 2018). Other barriers may include existing policies, procedures and administrative arrangements. For example, the cycle of government may lead politicians, bureaucrats or donors to focus more on short-term than long-term impact. Hence the urgency of raising awareness amongst policymakers and other decision makers of the need for "investment in a longer-term vision of *embedded evidence-based interventions*" (Morin 2018, p.6, emphasis added).

2.2 Personalized learning, AI and Big Data

In recent years, the notion of 'personalized learning' has become central to discussion of the potential of digital technology in education. Justin Reich at MIT saw it at "the frontline of the battleground between educationists with competing visions of the future of learning".[95] A broad consensus has emerged around the view that learning experiences should be tailored to the needs of each learner, and that this is enabled or facilitated by AI. According to the Villani report commissioned by the French Prime Minister, for example, AI opens up new opportunities to train a large number of individuals in a personalized and adaptive way (Villani 2018).

One application of AI involves the personalization of distance learning through intelligent conversational agents capable of following and accompanying students step by step in their progress, or at least answering students' questions in a relevant way. One example is Jill Watson — not a real person but the AI teaching assistant based on IBM's Watson platform (Goel and Polepeddi 2016; Eicher et al. 2017) — but this platform is still being tested and refined, and has yet to demonstrate potential for effective, large-scale deployment. It is also important to note here that AI is not new. As evidenced by the cases of the Algebra tutor developed by Carnegie Mellon University and AutoTutor developed by the Tutoring Research Group at the University of Memphis, intelligent tutors designed more than twenty years ago are already deployed in many classrooms. Furthermore, as is discussed below, there is a tension between the mass customisation models of differentiated or personalised technologies, and an aspiration to enable more diverse and open-ended learning.

Writing on the history of education in the United States in the 20th century, Ellen Lagemann (1989) characterized it as a battle of visions of learning between Edward Thorndike and John Dewey, in which Thorndike won. More than a century after Dewey (1916) published *Democracy and Education*, Lagemann's characterization is useful for coming to grips with some of the hyperbole around 'personalized learning' today. The mechanistic view of learning espoused by Thorndike dominated the latter half of the 20th century in the United States, culminating in the signing of the No Child Left Behind (NCLB) Act in 2002. Thorndike and Dewey had very different views on the nature of learning 'transfer'. According to Gibboney (2006), for Thorndike, learning to think in one subject simply increases one's intelligence, and the specific subject matter one learns is of less importance. This led many educators to question the value of academic subjects, a view to which Thorndike himself did not necessarily subscribe. For Dewey, school subjects exist to enhance the quality of democratic life. While Thorndike equated transfer of learning with intelligence measured by tests, Dewey believed in people's vast capacity for learning and espoused an expansive view of transfer, arguing that the goal of schools should be to foster an attitude, a desire for continued learning — the love of learning — and to provide means to effect that desire in practice. When a student learns something that is genuinely meaningful, in Dewey's vision of learning, what is transferred cannot be measured by numerical test scores.

The enthusiasm for the promises offered by AI must not hide the fact that its application in education raises serious questions. In a recent systematic review of 146 articles on AI in higher education (selected out of 2,656 publications between 2007 and 2018), Zawacki–Richterand et al. (2019) highlight the striking lack of critical reflection on the ethical implications of implementing AI applications in higher education as well as of theoretical and pedagogical perspectives in the studies analyzed. The Villani report advocates developing an enabling complementarity with AI by strengthening the place of creativity in education: "Indeed all forms of interaction are not desirable:

95 http://blogs.edweek.org/edweek/edtechresearcher/2012/06/battling_over_the_meaning_of_personalization.html

obeying the orders of AI, losing control over the processes, delegating decisions to the machine are all modes of complementarity, which, at the individual and collective level, will likely create suffering at work" (Villani 2018, p. 186, translation by the editors).[96] It is important to ensure that AI serves the aims of humans, rather than humans delegating decision-making to AI and eventually having to adapt to the needs of AI in an increasingly automated world.

In the educational context, it therefore becomes critical to enable learners to understand and use their own learning data, working closely with their teachers. For this to happen, it is critical to promote the teachers' mastery of dashboards which present collected, analyzed and synthetized data on their students. As Barbara Means' (2010) study on the implementation of mathematics and reading software in schools clearly showed, technology adoption and implementation require not just financial resources but also ongoing effort on the part of educators. The use of software-generated student performance data was one of the largest differences between high-gain and low-gain implementations of instructional software, and also in terms of managing the classroom effectively. The study concluded that teachers should be urged to capitalize on the assessment data that instructional software makes available and that training and support around instructional software should pay more attention to the details of classroom management (Means 2010).

It is important to ensure that AI serves the aims of humans, rather than humans delegating decision-making to AI and eventually having to adapt to the needs of AI in an increasingly automated world.

As recent studies show, more research and capacity development efforts are required to ensure that teachers effectively and responsibly use student learning data to inform their practice (Mandinach and Jimerson 2016; Bertrand and Marsh 2015). Furthermore, fulfilling the promise of understanding and improving learning through data requires not only building capacities of teachers and students to use the processed data but also going beyond machine learning models dedicated to the sole purpose of making accurate prediction. According to a recent article by a group of researchers from Carnegie Mellon University, using 'black box' models inside applications such as recommender systems will most likely fail: "the recommender system will not be transparent enough to adapt in an insightful way to the individual needs of students nor to the context of use" (Rosé et al. 2019, p. 2945). They recommend bringing interdisciplinary expertise "to develop *explanatory learner models* that provide interpretable and actionable insights in addition to accurate prediction", rather than relying on AI expertise alone (ibid. p.2943).

The diametrically opposed camps disputing the merits of 'personalized learning' today echo the divide between Thorndike's and Dewey's visions of learning. Thorndike was an advocate of an education science driven by objective measurement; Dewey was an advocate of making schools look like life, which made the outcomes harder to capture in numbers. At one end of the continuum of personalization, to borrow Justin Reich's words, personalized learning means "using technology to individually diagnose student competencies on standardized tests and then apply algorithms to adaptively deliver appropriately challenging content to each student to help them perform better on those tests". Reich analogizes this as "taking the factory model of education and giving every kid an assembly line." This type of AI-driven personalization technology epitomizes Thorndike's mechanical view of learning. The recent fascination with AI cannot be understood without considering big data — which allow "human and societal behaviour to be objectively quantified and, therefore, easily tracked, modelled and, to a certain extent, predicted" (UNESCO 2019b, p.7). At the other end of

96 The original text in French reads as follows : « En effet toutes les formes d'interactions ne sont pas souhaitables : obéir aux ordres d'une intelligence artificielle, perdre le contrôle sur les processus, déléguer les décisions à la machine sont autant de modes de complémentarité, qui, au niveau individuel et collectif, seront susceptibles de créer de la souffrance au travail. » See https://www.aiforhumanity.fr/en/ and https://www.aiforhumanity.fr/pdfs/MissionVillani_Report_ENG-VF.pdf for the English translation of some sections of the Villani report. A useful description of what AI is can be found at: https://www.aiforhumanity.fr/pdfs/MissionVillani_WhatisAI_ENG(1)VF.pdf

the continuum, some advocates of personalized learning envisage digital technology enabling everyone to access a world of abundant information, rich expertise and innumerable resources, creating content themselves and sharing it with others, and following their interests in fluid ways in diverse directions. The next section focuses on this latter meaning of 'personalized learning' as constitutive of the essence of participatory culture, which can be defined as "a culture with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing one's creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices" (Jenkins 2006, p. 3).

2.3 The 'Social Turn' in learning with technology

While there is much interest in the neurobiological basis of learning, the broad field of learning sciences has gone through what Stanford learning scientist Roy Pea has called the "Social Turn".[97] Increasing attention is paid to the social foundations of learning, and learning is seen as involving not only transformation of cognitive structures but also of participation in cultural practices. Writing on the resurgence of interest in teaching computer programming in K-12 schools in recent years, after the initial excitement in teaching Basic, Logo, or Pascal programming in schools which subsided by the mid-1990s, Yasmin Kafai and Quinn Burke (2013) point to a shift "from a predominantly individualistic view of technology to one that includes a greater focus on the underlying sociological and cultural dimensions in learning programming and reconceptualizing computational thinking as computational participation", calling it a "social turn" (p.63). They identified three major shifts in learning programming — (1) from code to applications ("from the study of an abstract discipline to a way of making and being in the world digitally"), (2) from tools to communities, and (3) from creating from scratch to creating via remix in the spirit of the open-source movement (Kafai and Quinn 2013, p. 63).

Learner motivation, interest, and persistence are key considerations in understanding the impact of technology-based pedagogy. Identifying design features that can increase the instructional effectiveness of computer games through experimental studies does not help explain how these features influence motivational processes. For cognitive psychologists, answering this 'black box' problem is typically assumed to involve a closer look at the neurobiological basis of learning, through "techniques for measuring cognitive and motivational processes during learning, including eye tracking, physiological measurements, and cognitive neuroscience measures such as electroencephalography or functional magnetic resonance imaging" (Mayer 2019, p.539). In contrast, work informed by the 'social turn' focuses on social interactions which contribute significantly to key drivers of learning such as identity, agency, engagement, and social networks. The John D. and Catherine T. MacArthur Foundation has funded many reports and studies investigating the power of informal learning unleashed by the kind of digital media commonly used by young people.[98] **Box 4-3** summarizes a set of competencies required by participatory culture, as identified by one such report, as well as new opportunities and challenges associated with the use of digital media.

97 https://www.slideshare.net/roypea/roy-pea-lpch061010

98 See https://mitpress.mit.edu/books/series/john-d-and-catherine-t-macarthur-foundation-reports-digital-media-and-learning for The John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning, which "present findings from current research on how young people learn, play, socialize, and participate in civic life." The MIT Press also publishes books in The John D. and Catherine T. MacArthur Foundation Series on Digital Media and Learning, which is founded upon "the working hypothesis that those immersed in new digital tools and networks are engaged in an unprecedented exploration of language, games, social interaction, problem solving, and self-directed activity that leads to diverse forms of learning". See https://mitpress.mit.edu/books/series/john-d-and-catherine-t-macarthur-foundation-series-digital-media-and-learning for titles.

Box 4-3 Competencies required in participatory culture in the digital age

In the white paper *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century*, Henry Jenkins (2006), director of the Comparative Media Studies department at MIT, put forward a concept of participatory culture that defines the lives of youth in the Internet age. The report identified the following core competencies that young people require to be "full, active, creative, and ethical participants in this emerging participatory culture".

- **Play** — the capacity to experiment with one's surroundings as a form of problem-solving
- **Performance** — the ability to adopt alternative identities for the purpose of improvisation and discovery
- **Simulation** — the ability to interpret and construct dynamic models of real world processes
- **Appropriation** — the ability to meaningfully sample and remix media content
- **Multitasking** — the ability to scan one's environment and shift focus as needed to salient details
- **Distributed Cognition** — the ability to interact meaningfully with tools that expand mental capacities
- **Collective Intelligence** — the ability to pool knowledge and compare notes with others toward a common goal
- **Judgment** — the ability to evaluate the reliability and credibility of different information sources
- **Transmedia Navigation** — the ability to follow the flow of stories and information across multiple modalities
- **Networking** — the ability to search for, synthesize, and disseminate information
- **Negotiation** — the ability to travel across diverse communities, discerning and respecting multiple perspectives, and grasping and following alternative norms.

With the rise of ubiquitous networked devices, participatory culture seems to be becoming a part of everyday life in many parts of the world. For many people — both young people and adults — today, digital media and technology provide ways to express identity and cultivate and maintain essential social relationships. In what has become a foundational text in the field of digital media and learning, Ito et al. (2009) explored American middle-class youth's use of digital media based on a three-year ethnographic investigation and summarized the ways in which young people engage with and through online digital platforms as a HOMAGO framework: "hanging out, messing around, and geeking out".

This study provided new insights into interest-driven learning in informal settings enabled by digital media. However, the rather familiar idea that digital technology connects learners in novel and powerful ways and liberates learning from past conventions has its dark sides. Now unfettered by the need (or constraint) to learn and work with those in our immediate contexts, digital technology makes it easy for us to interact and learn with other people of our own choosing. One concern is how such shifts sit with the traditional values and desires of 'public education' — that is, education as a public good rather than private interest, and learning as a social rather than solipsistic undertaking. There are also new problems accompanying the rise of new digital media and platforms, ranging from social media addiction, online youth radicalization to issues of data privacy and security.

At one level, the challenge for educators is to link this interest and familiarity with new digital media to learner engagement and outcomes. For example, Herr Stephenson et al. (2011) investigated how afterschool programmes, libraries, and museums use digital media to support extracurricular learning. At the same time, educators are also tasked to equip students with skills needed to detect instances of disinformation online and use digital media safely and responsibly.

Perhaps the notion of 'connectivism' most vividly captures the vision of learning as participation, rather than simply knowledge acquisition (see **Box 4-4**). Connectivism upholds a thesis that knowledge is distributed across networks, and thus views relationships and social interactions as central to learning (Siemens 2005, Downes 2010). A learner is immersed within a community of practitioners and introduced to ways of doing what practitioners do, in ways conducive to the acquisition of the competencies common to members of that community. In connectivist learning, the role of teachers changes from transmitting information to guiding students to information and encouraging them to seek out information on their own online.

Although connectivism provides insights into learning skills and tasks needed for learners to flourish in a digital era, it stops largely at describing how people seek information and interact online. There is a need to extend beyond the notion of connectivist learning and understand better how learning is conceptualized in the design and deployment of digital technologies. To this end, Castañeda and Selwyn (2018, p.3) call for giving full consideration to "how established self-regulation mechanisms of learning are challenged by the use of technologies", citing Azevedo's (2009) work on metacognition and self-regulated learning and Dabbagh and Kitsantas' (2012) work on a "Personal Learning Environment" (a pedagogical approach to integrate formal and informal learning using social media and to support self-regulated learning in higher education contexts). Furthermore, engaging with the idea of technology use as a collective social endeavour requires paying more attention to "the interplay between the use of digital technology and people's emotions, feelings and affect" (Castañeda and Selwyn 2018, p.4).

Box 4-4 Beyond 'content vs pedagogy' and 'acquisition vs participation' dichotomies

There has long been a tendency to treat 'content' and 'pedagogy' as separate and somewhat competing in education (Seixas 1999). This dichotomy between 'content' and 'pedagogy' is a classic problem, preceding the launch of the World Wide Web in 1995 or even the development of the Internet in the 1980s. More than a century ago, John Dewey attributed the split between "method and subject matter of instruction" to the Western philosophical tradition which treats "mind and the world of things and persons" as "two separate and independent realms" (Dewey 1916 as cited in Seixas 1999, p.317). This dichotomy also reflects tensions between subject-matter experts (who usually sit at a university and write textbooks) and classroom teachers. When subject matter is understood as "ready-made systematized classification of the facts and principles of the world of nature and man [sic]", pedagogy then becomes "a consideration of the ways in which this antecedent subject matter may be best presented to and impressed upon the mind" (Dewey 1916 as cited in Seixas 1999, p.318). Lee Shulman (1986) visited the same problem and tried to resolve this dichotomy with the notion of "pedagogical content knowledge", which paved the way for what later became a major research field of TPACK (see **Figure 1-1** in Chapter 1).

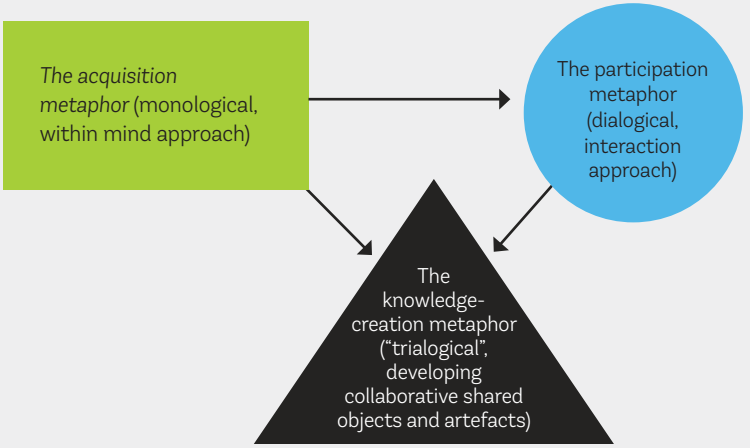
While the rationale for promoting the use of digital technology in education often assumes that learning is no longer about individual knowledge acquisition, this does not mean that we are getting rid of the acquisition metaphor. On the contrary, "[the] idea that new knowledge germinates in old knowledge has been promoted by all of the theoreticians of intellectual development, from Piaget to Vygotsky to contemporary cognitive scientists" (Sfard 1998, p.4). The acquisition metaphor is also strongly linked to a nation-state deciding what the younger generations must acquire through schooling and what the older generations wish to pass on to the younger ones. Although it is open to question whether such prescription is desirable or essential, many embrace, at least rhetorically, a shift from teaching as imparting a set of prescribed

knowledge and subject-based instruction to project-based learning that helps students think across subject-matter disciplines (see, for example, Schleicher 2018).

As **Timeline 3** illustrates, digital technology has contributed to 'opening up' education significantly. This is seen in various developments in the last two decades, such as the launch of the MIT OpenCourseware in 2002 and the growth of MOOC platforms in the 2010s. In addition to the Internet, the rise of free digital media such as Wikipedia and Creative Commons, social media (e.g., Facebook, Twitter, Instagram) and massively scaled-up media distribution platforms (e.g., YouTube) has given a renewed significance to the notion of learning as always situated and taking place in interaction with others. Talk of 'the digital age' resonates strongly with a vision of learning as a dynamic and evolving result of complex interactions primarily taking place within communities of people. This vision also emphasizes that learning is a process of constructing meaning, not a matter of accepting fixed facts.

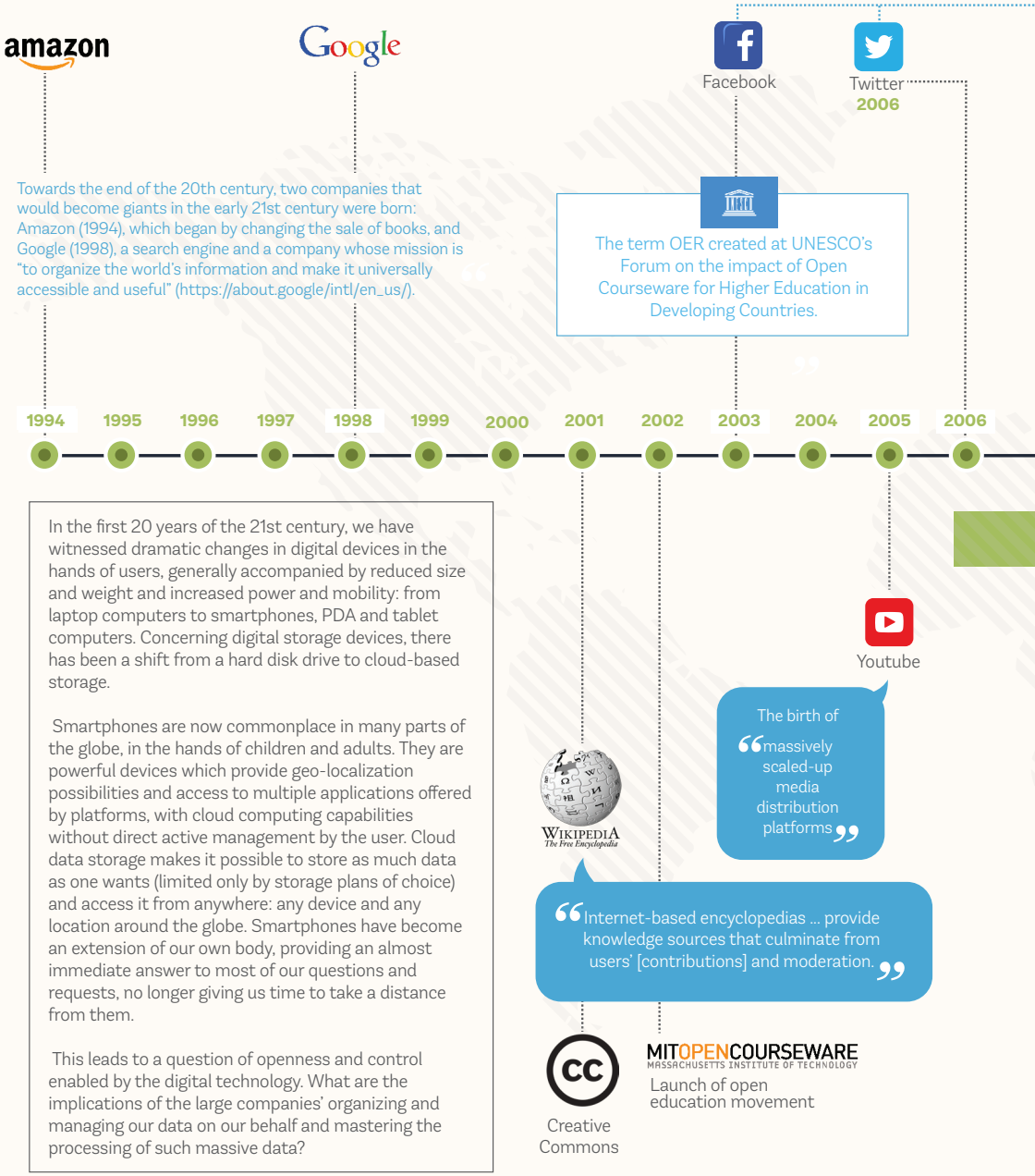
The two metaphors for learning — learning as 'acquisition' and learning as 'participation' (Sfard 1998) — form another enduring dichotomous formulation in education. As Sfard (1998) warned two decades ago, however, education has always been about both acquisition and participation, and it is dangerous to embrace one and dismiss the other. There is no universal model that applies to all levels of education, as instructional methods need to be age appropriate. The closer we get to the professional world, the more we learn in a participatory mode, as in internships and service learning.

Figure 4-2 Three metaphors of learning by Paavola and Hakkarainen (2005)

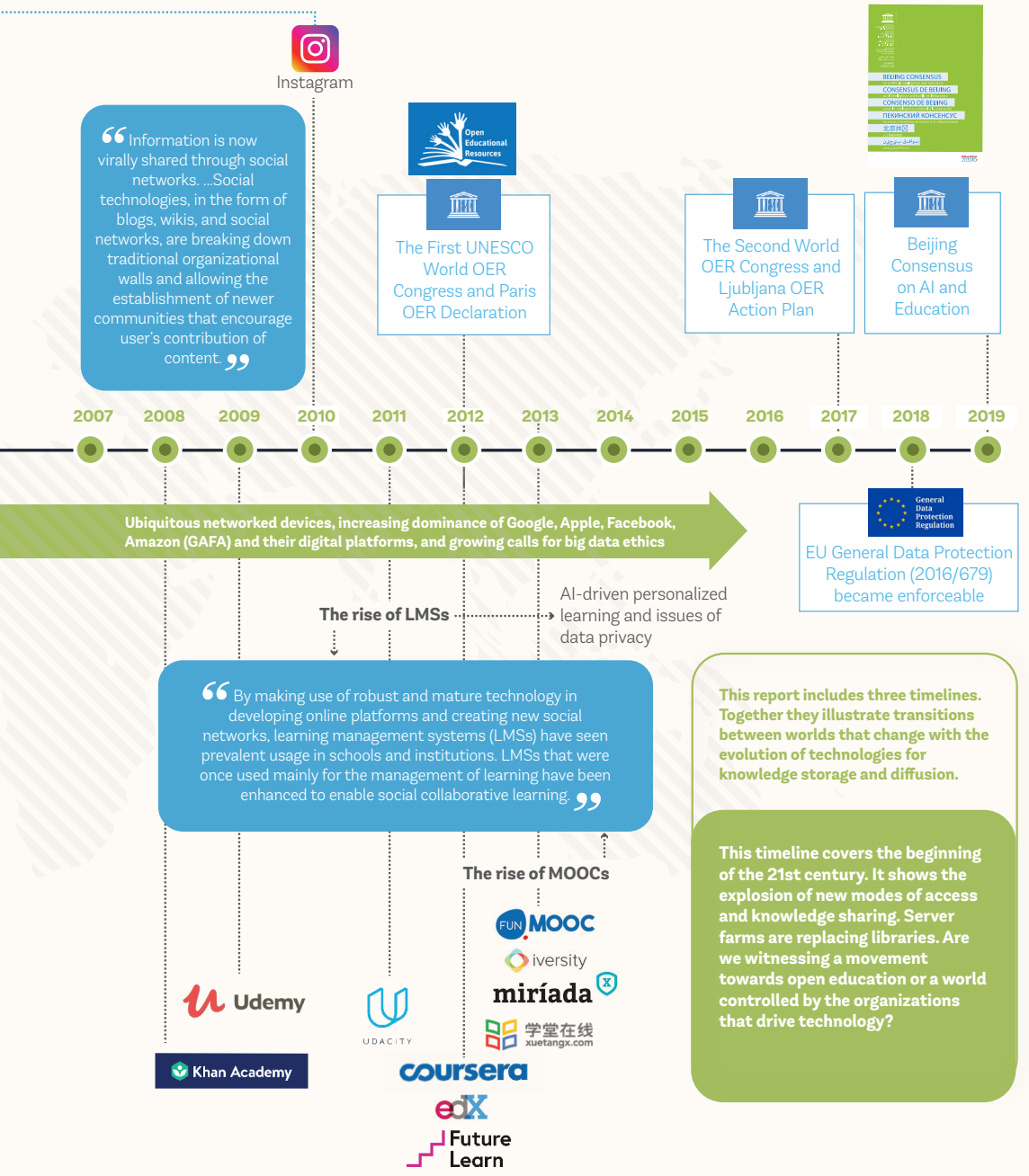


Paavola and Hakkarainen (2005) of Helsinki University added another metaphor of learning as a process of knowledge creation, arguing that this third metaphor helps us to understand processes of knowledge advancement that are important in a knowledge society. While researchers have in general relied on learning theories developed without consideration of digital technology, some have proposed that the field needs to have a theory tailored for the unique challenges that confront those trying to understand the complex interplay of technology and learning.

Timeline 3 **Openness and control with digital media of the 21 century: New opportunities and challenges**



Source: All direct quotes are from Tan and Lee, 2018, p.4.


Instagram
“Information is now virally shared through social networks. ...Social technologies, in the form of blogs, wikis, and social networks, are breaking down traditional organizational walls and allowing the establishment of newer communities that encourage user's contribution of content.”
Open Educational Resources
The First UNESCO World OER Congress and Paris OER Declaration
The Second World OER Congress and Ljubljana OER Action Plan
Beijing Consensus on AI and Education
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
Ubiquitous networked devices, increasing dominance of Google, Apple, Facebook, Amazon (GAFA) and their digital platforms, and growing calls for big data ethics
General Data Protection Regulation
EU General Data Protection Regulation (2016/679) became enforceable
The rise of LMSs
AI-driven personalized learning and issues of data privacy
“By making use of robust and mature technology in developing online platforms and creating new social networks, learning management systems (LMSs) have seen prevalent usage in schools and institutions. LMSs that were once used mainly for the management of learning have been enhanced to enable social collaborative learning.”
The rise of MOOCs
FUN MOOC
iversity
miríada
学堂在线 xuetangx.com
Udemy
UDACITY
Khan Academy
coursera
edX
Future Learn
This report includes three timelines. Together they illustrate transitions between worlds that change with the evolution of technologies for knowledge storage and diffusion.
This timeline covers the beginning of the 21st century. It shows the explosion of new modes of access and knowledge sharing. Server farms are replacing libraries. Are we witnessing a movement towards open education or a world controlled by the organizations that drive technology?

2.4 Making education more equitable and transformative

At a time when the entire content of K-12 textbooks can fit into a USB flash drive and the Internet seems to put the whole world at our fingertips, some forcibly argue that we no longer need content experts. In a digital age, the 'content vs. pedagogy' dichotomy (see **Box 4-4**) has gained a new traction, now often privileging 'pedagogy' and at times relegating 'content' as secondary or even irrelevant to discussion of learning. This is partly reflected in talk about 'competencies' that are not linked to any specific subject area. Coupled with the idea that technology grants immediate access to everything we need to know, this has given rise to a chorus of calls for 'learning to learn'. However, this seemingly progressive notion needs to be understood against the backdrop of standards-based education reforms across the early 21st-century world, involving the adoption of standardized testing. Whether people are calling for 'learning to learn', personalized learning, or social and emotional learning (SEL), the goal is often to improve individual student performance measured against a given set of metrics. This practice may actually undermine 'genuinely educational goals' such as fostering engaged citizenship, valuing diversity or shaping a peaceful and sustainable society.

UNESCO has affirmed its humanistic approach to education that embraces whole-person development (International Commission on the Development of Education 1972; International Commission on Education for the Twenty-first Century 1996; UNESCO 2015a). The concept of education as a human right is embedded in the UNESCO Constitution as a right to "full and equal opportunities for education for all." In 1972, UNESCO's first seminal report on the future of education, known as the Faure Report, already pointed out that education had reached "dead ends": "Traditional formulae and partial reforms cannot meet the unprecedented demand for education arising out of the new tasks and functions to be fulfilled" (International Commission on the Development of Education 1972, p. vi). UNESCO's second seminal report *Learning: The Treasure Within*, commonly referred to as the Delors Report, proposed four pillars of learning: learning to know, to do, to be, and to live together, which rearticulated the principles of whole-person development and emphasized the critical importance of "learning to live together" in the interconnected and interdependent world (International Commission on Education for the Twenty-first Century 1996).

What do the findings of recent large-scale studies tell us about the implications of 'going digital' in terms of embracing a humanistic approach to education championed by UNESCO? Advocates of digital education have hoped that digital resources would be less dependent on teacher quality and other factors and therefore could contribute to closing gaps in access and achievement. This section first looks at what recent literature suggests about the impact of 'going digital'. It then explores what may constitute transformative pedagogy in a digital age.

(1) Making the benefits of digital transformation available to all

Does research show that going digital cuts costs, improves learning outcomes, or reduces inequalities? Overgeneralized claims that the use of digital resources is cost efficient are contestable. For example, in countries with weak infrastructure in sub-Saharan Africa, the cost of providing digital reading materials was estimated as being 20 to 60 times more expensive than providing print materials (Fredriksen, Brar and Trucano 2015). So far, one-to-one (1:1) educational technology programmes such as One Laptop Per Child (OLTP) have seen limited success despite substantial investment in distributing devices. This is because they often lack a vision of the purpose

of introducing technology into the classrooms and how technology is to be integrated with teaching and learning goals (Smart and Jagannathan 2018; World Bank 2017; RTI International 2013).

While there have been large-scale investments in ICT for education in many countries, there is little evidence that digital classrooms lead to improved learning. In *Students, Computers and Learning: Making the Connection*, for example, OECD (2015, p.15) reports that "PISA results show no appreciable improvements in student achievement in reading, mathematics or science in the countries that had invested heavily in ICT for education". This made headlines in newspapers, as it seemed counter-intuitive to the general public. Nevertheless, it did not surprise researchers in the field. Indeed, as far as technologies in education systems are concerned, comparable results have been reported over the past 30 years: no or minimal effect on academic performance, which has been dubbed as the "no significant difference phenomenon" in media comparison studies in education research.[99]

With the growth of digital education resources, there is now compelling evidence that "new technologies tend to be used and accessed in unequal ways, and they may even exacerbate inequality" (Reich and Ito 2017, p.3). One case in point is MOOCs. According to an annual analysis of the global MOOC landscape by Class Central[100], the number of students taking MOOCs crossed 100 million in 2018, with a continued trend of increase in paying users and shifting away from the initial ambition of MOOC developers to democratize education.[101] Although advocates for free MOOCs have heralded them as vehicles for closing gaps in access and achievement within and across countries, research shows that the socio-economically privileged enroll in and complete MOOCs at relatively higher rates (Hansen and Reich 2015; Kizilcec et al. 2017).

Using data from 68 MOOCs offered by Harvard and MIT between 2012 and 2014, Hansen and Reich (2015) found that, in the United States, course participants were likely to live in wealthier and better-educated neighborhoods than the average U.S. resident, and that MOOC students with greater socioeconomic resources were more likely to receive certificates. At a global scale, using data on 1.8 million learners enrolled in 55 MOOCs created by Stanford University and offered on the Coursera platform between 2013 and 2015, Kizilcec et al. (2017) examined the relationships between country-level affluence (country's Human Development Index score) and MOOC participation. They found that course participants in wealthier countries are much more likely to complete MOOCs and earn certificates. These findings raise concerns that MOOCs and comparable approaches to online learning can widen gaps in educational outcomes related to socioeconomic status.

A decade ago, Allan Collins and Richard Halverson (2009) cautioned against the potential of digital technology in undermining equality and social cohesion by further weakening the role of public education as a social equalizer and a socializing institution. As Chapter 3 shows, digital technology has made strides in building low-cost and universally accessible education media and resources (see **Appendix I** for a list of resources sampled). However, concerted efforts are needed to allow them to contribute to equity in and through education. The growth of online courses has made it possible to carry out large-scale data collection on the students' socio-economic backgrounds and their persistence and achievement in these courses as well as field experiments to test interventions to address achievement gaps (Kizilcec et al. 2017; see **Box 4-5**). This creates opportunities to further investigate and tackle obstacles to achieving equitable quality education through digital technology,

99 See, for example, the No Significant Difference database at https://detaresearch.org/research-support/no-significant-difference/ This database was established in 2004 as a companion piece to Thomas L. Russell's (2001) book "The No Significant Difference Phenomenon", a research bibliography of 355 research reports, summaries and papers that document no significant differences in student outcomes between alternate modes of education delivery. The website, revamped in 2010, serves as an ever-growing repository of comparative media studies in education research.

100 Class Central is a search engine that helps potential learners find online courses that interest them.

101 https://www.classcentral.com/report/moocs-stats-and-trends-2018/

although there are challenges to this type of research, especially when the participants are minors, due to data privacy and other concerns.

Making the benefits of digital transformation available to all, including the least privileged learners, remains to be a major challenge. However, the successful example of no-cost and easy-to-implement interventions discussed in **Box 4-5** gives hope to the possibility of making digital education resources a key enabler for achieving SDG 4. It also highlights the importance of addressing the 'second digital divide' (Attewell 2001) by paying attention to the social, cultural and psychological barriers to digital learning.

Box 4-5 Field experiments to address achievement gaps in MOOCs

While gaps in MOOC completion across countries are often attributed to hindrances in developing countries such as unreliable Internet connection, researchers at Stanford and MIT, in a recent article appeared in *Science*, reported the findings of their investigation into another overlooked cause of underperformance by the less advantaged learners, namely, "the cognitive burden of wrestling with feeling unwelcome while trying to learn" (Kizilcec et al. 2017, p.251). To test whether psychological barriers may be one cause of the low completion rate for learners from developing countries, they implemented interventions that targeted "social identity threat" (the fear of being seen as less capable because of one's group) in two MOOCs. The interventions were simple writing exercises in a pre-course survey, randomly assigned to students: (1) a belonging intervention which asked students to write about what it felt like to belong in an online community and (2) a value-affirmation intervention which asked students to write about how taking a course reflected values they held dear. In a control condition, a typical global achievement gap was identified, but when the two interventions were applied, students from developing countries persisted and completed the course at the same rates as those from more developed countries.

(2) Transformative pedagogies for sustainable development in a digital age

With constant technological and social change — what sociologist Zygmunt Baumann (2000) characterized as "liquid modernity" — and the seeming failures of the project of modernity from climate change to widening inequalities, the world has come to be seen as ever more complex and subject to uncertainty and risk. In the field of sustainability education, this understanding has informed calls for fostering 'social learning' in the search for solutions to various contemporary challenges (see, for example, Wals 2007). As we are dealing with the 'wicked' problems to which we have no simple right or wrong answers, we need to learn to change by changing how we learn (Glasser 2019). Here sustainability education advocates and digital learning advocates merge in their embrace of a new vision of learning which is more participatory and collaborative, although we need to be cognizant of the danger of positing a stereotyped vision of 'old' learning as individualistic and hierarchical, and 'new' learning as collaborative and participatory.

Not only has technological advancement enabled new ways of presenting, archiving and interacting with content, it has also allowed new ways of creating and sharing content. Digital technology provides new types of media that can facilitate problem-based and project-based approaches and foster collaborative learning. In their article calling for bridging the gaps between science education (which tends to focus on knowledge and skills) and environmental education (which puts additional emphasis on values and behaviour change), Wals et al. (2014, p.584) point out the potential of "ICT-

supported citizen science" in providing "opportunities for new forms of education that can lead to the engagement of seemingly unrelated actors and organizations in making new knowledge and in taking the actions necessary to address socioecological challenges." Echoing 'participatory culture' and 'connectivist' thinking discussed earlier, they argue that citizen science enabled by digital media (monitoring of environmental changes based on the crowd-sourcing of scientific data) has the potential to constitute a transformative pedagogy for sustainability, with the data collected and shared digitally providing "useful input to environmental scientists while simultaneously empowering citizens to engage in ongoing debates about local and global sustainability issues and what needs to be done to address them" (ibid.).

If ICT-supported citizen science is one form of experiential learning which encourages people to go outdoors and deepen their experience of the physical place (such as forest, river and ocean, through air, water or soil quality monitoring, for example), another, radically different form of experiential learning in a virtual world is provided by gaming. For some games and learning researchers, games have the potential to offer unique forms of experiential and embodied learning. For example, Sasha Barab's notion of "transformational play" (Barab, Gresalfi and Ingram-Goble 2010) has relevance to transformative pedagogy for sustainable development. The notion of transformational play has emerged through research on games for learning at Arizona State University, where Barab co-founded the Center for Games and Impact. Transformational play involves positioning students as empowered actors who must deploy academic content in order to effectively overcome problematic scenarios encountered in the game. Transformational play, therefore, takes an approach fundamentally different from the approach of 'chocolate-covered broccoli' often employed in educational games. Rather than 'sugar-coating' academic content so that students can be tricked into swallowing it, the game establishes a virtual world where children are transformed into empowered scientists, doctors, reporters, and mathematicians who have to understand disciplinary content to accomplish desired ends. This has implications for transformative pedagogies for sustainable development, as such games can create a digital world where what students know and use is directly linked to what they can do, which in turn has significant impact on that world.

While some emphasize that digital technology achieves a new pedagogy fundamentally different from pedagogical forms that have existed in the pre-digital age, others argue that digital technologies make it much easier to realize many long-held pedagogical ideals. For example, Cope and Kalantzis propose seven affordances of digital technology that enable new learning and assessment opportunities and experiences (Kalantzis and Cope 2015; Cope and Kalantzis 2017). These seven affordances are: ubiquitous learning, active knowledge making, multimodal meaning, recursive feedback, collaborative intelligence, differentiated learning, and metacognition (explained in the next section). The notion of 'affordance' is used here to indicate that technology makes it *logistically* easier to implement some long-desired pedagogical approaches. However, it is essential to remember that the same technology can be used either for surveillance or collaborative intelligence, for indoctrination or fostering critical thinking. Textbooks do not in themselves lead to rote learning. The same factors that encourage rote learning via textbooks could lead to rote learning via digital resources. It is up to human beings, through the organizations and institutions we create, to steer digital learning towards advancing desirable pedagogical and social outcomes.

3. The 8A Framework and its Pedagogical Implications

This section proposes a conceptual framework that we call the Eight Affordances (8A) framework. This adds an eighth affordance — accessibility — to the framework of seven affordances introduced in the previous section (Kalantzis and Cope 2015; Cope and Kalantzis 2017). It is important to reiterate here that many of the pedagogical objectives in the 8A framework can be achieved in non-digital learning contexts. Technology can potentially ossify what can be termed 'instructivist' or transmission pedagogies and narrowly focused modes of assessment, rather than enabling 'constructivist', 'constructionist', 'connectivist' or transformative pedagogies. The affordance offered by the digital consists in the relative ease and cheapness with which it allows certain objectives to be realised, thus enabling wider access to quality learning. But the deployment of digital resources does not in itself guarantee that these educational objectives will be met. This is why the word 'affordance' is important — these are opportunities that digital technology offers. Affordances are possibilities, and this means that the model is not based in technological determinism.

Before presenting the 8A framework, it is important to clarify our intentions. First, the goal is not to recommend certain types of digital products for adoption or to suggest an inevitable shift from anachronistic 'analogue' pedagogy to innovative 'digital' pedagogy. Nor do we seek to make a case for a new regulatory framework that addresses the educational quality of digital resources. Textbooks are regulated in vastly different ways by national authorities across countries, ranging from state production of textbooks through formal state textbook approval systems to a complete absence of any state-directed screening procedure (Wilkens 2011). Links between the quality of educational materials and learning outcomes are complex, and quality assurance mechanisms for educational resources — whether paper or digital — can only partially address pedagogical issues.

Second, while we are fully cognizant of the importance of social justice and equity to sustainable development, the 8A model does not address them directly as these are not issues that can be afforded by technology *per se*. There is extensive literature that warns against conflating equity with equality and access (see UNESCO-UIS 2018 for an overview). Therefore, the eighth affordance of accessibility takes into account the possibilities of OERs as well as the importance of interoperability and Universal Design for Learning (UDL) principles, without suggesting that digital learning resources *per se* contribute to equity and fairness.

In this section, we look towards possibilities for innovative applications of technology which enhance the learner experience and improve learner outcomes. This conceptual tool provides an overall framework and a set of indicators (see **Appendix II**) to assist educators in discerning digital educational resources that can potentially be effective and appropriate for contemporary challenges, across subject domains. The 8A framework helps us imagine the range of possibilities for pedagogies enabled or facilitated by digital technology.

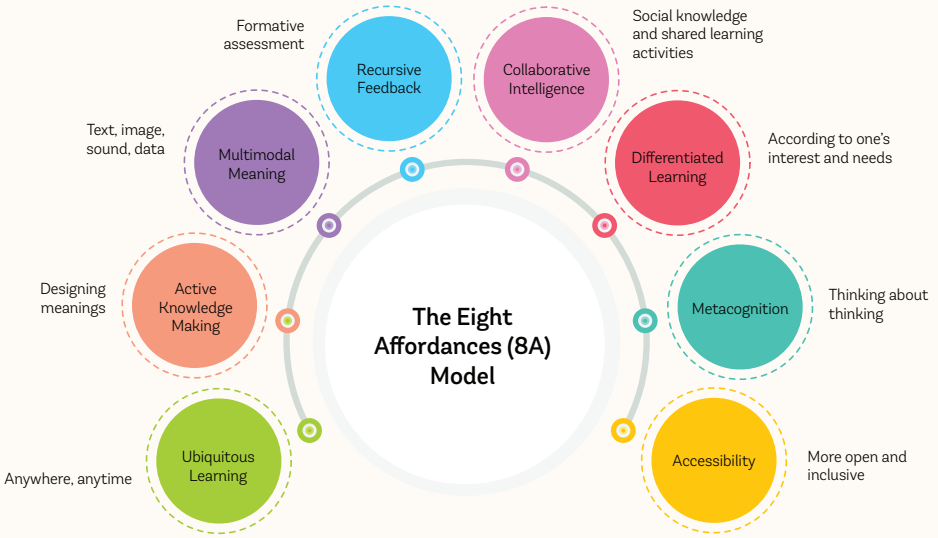
3.1 Eight affordances of the digital

Figure 4-3 presents the eight key affordances of digital educational resources. Below we define and explicate each affordance and indicate examples of the kind of active pedagogy associated with it. **Appendix II** provides a table with a tentative set of indicators for each affordance — derived from various frameworks (Brown, Dehoney, and Millichap 2015; Hegarty 2015; Gómez-Zermeño and Alemán 2012, 2016; Kalantzis and Cope 2015; Cope and Kalantzis 2017; UNESCO-UIS 2009;

UNESCO 2018a) and newly compiled for this review — which might be used for assessing their realization in practice. The set of indicators should be used thoughtfully, keeping in mind the caveats earlier on in this chapter concerning the usefulness or appropriateness of metrics in assessing the quality of education.

The 8A framework is content-agnostic, and transcends disciplinary divides, educational levels, and cultural orientation. While many of these affordances can be — and indeed are — harnessed for online youth radicalization or personalized advertising, the framework as a whole emphasizes active citizenship, the responsibilities of learners as knowledge producers, the ethics of collaboration, recognising and harvesting productive diversity, and the use of big data and AI as a constructive part of learning rather than for the kind of learner profiling that reproduces inequalities.

Figure 4-3 The 8-Affordances Framework for exploring pedagogical possibilities of digital educational resources



(1) Ubiquitous Learning

The notion of ubiquitous learning is an extension of an everyday reality that is today called "ubiquitous computing," or the ready availability of interconnected computing devices, many of which are portable or, when fixed, offer 'cloud' access to shared spaces.

As a consequence, learners can access learning spaces and content anytime, anywhere. Such an affordance allows formal learning to break out of the spatial confinement of classrooms and the temporal confinement of timetables. In these ways, ubiquitous computing offers new opportunities for ubiquitous learning. It extends the *action space for learning,* blurring the traditional boundaries of space and time.

This may be achieved by mobile devices such as laptop computers, tablets or phones, but not necessarily. With web-based applications, students can access educational resources via desktop computers in computer labs in school, at home, or in public libraries, for instance.

Since the traditional boundaries of the classroom are no longer necessarily a limiting factor, the use of thoughtfully designed technologies in school can open up opportunities for learning both within and outside schools. For instance, school-community interactions can be facilitated with the help of digital tools.

Ubiquitous digital tools also defy geographical constraints and offer opportunities to collaborate and create partnerships with learners and educators all over the world. And all of these possibilities can be achieved with much lower costs than the erstwhile channels of physical communications. Moreover, this affordance also offers opportunities for individualized learning where curious learners can pursue their various learning pathways at their convenience.

Importantly, in line with the demand of SDG 4 and 4.7, one can hope that such a capability offered by digital media would also produce habits of mind appropriate to our times — nurturing lifelong learners who would be able to seek, learn, share and shape knowledge throughout their lives.

(2) Active Knowledge Making

One of the key challenges for an education that fosters skills to contribute to a more sustainable world is for students not only to acquire subject-oriented knowledge, but also to recognize problems and challenges that surround us and explore ways to solve them. Active knowledge making can support exactly these approaches: students are encouraged to discover things, understand challenges and find solutions by actively making things and constructing knowledge.

It is widely acknowledged that learning is engaging and effective when there is active construction of knowledge and understanding (Cope and Kalantzis 2017). Active knowledge making practices underpin the contemporary emphasis on innovation, creativity and problem solving as competencies essential for the 'knowledge economy' and 'knowledge society'. Learners build upon existing knowledge or on what they already know. This means that it is necessary to identify and implement a variety of activities that are both content and process oriented. The learning process involves making new connections between pieces of information in order to construct meanings for oneself. This requires learners to become active knowledge producers, and not merely knowledge consumers.

Interactive digital technologies provide tools that are "objects-to-think-with" (Papert 1980, p.11). New possibilities emerge in experiential learning where learners engage in meaning making and knowledge construction within the real or virtual space of "microworlds" (Papert 1980, p.117). "Microworlds" and tools are all-inclusive environments that enable learners to be totally immersed in experimenting within the same closed setting. They can be characterised by an action space with a set of controls and constraints to enable learners to get actively engaged with the agents and environments. This possibility is remarkably different to the transmissive pedagogies of rote learning and memorization or even merely theoretical information gathering as learners are engaged in a discovery-oriented and adventurous learning process.

(3) Multimodal Meaning

"The universe is made of stories, not of atoms," American poet and political activist Muriel Rukeyser (1913-1980) said. Much of our everyday representational experience is fundamentally multimodal. However, the traditional methods and teaching-learning toolbox consisting of books, pens and vocal chords, are limited by *what* and *how much* they can represent. By comparison, digital technologies possess multiple and powerful ways of representation with a combination of text, image, audio, video, simulation, interactive, immersive environment, virtual and augmented reality and so forth. That is, concepts and information content can be represented or perhaps enacted multifariously in different modes and forms and thereby allowing learners to understand things in many different modes — textual, oral, visual, spatial and embodied (Kalantzis et al. 2016).

Research suggests that multimodal resources can cater more effectively to diverse learners (Cope and Kalantzis 2017). With multimodal representation learners get empowered to not only choose preferred media, have concepts reinforced but they could also make multiple meanings including meanings unthinkable in traditional forms of representation. For instance, a simulation of solar system with planetary motion could, arguably, be more interesting and conceptually clearer than a printed or a verbal explanation from a teacher. The use of digital applications can enrich ESD practices, for example by enabling the use of real-time data in spatial analysis for weather and disaster monitoring, or through simulations of the feasibility of certain solutions to address SDGs (Engagement Global 2018).

Importantly, the multimodal meaning making affordance of digital learning resources contributes to SDG 4. Together with the Accessibility affordance, the usage of different environments and media types can support a wide range of learners. The opportunity to choose between different paths to acquire knowledge and skills contributes to the different ways of learning and understanding of students, offering a range of media for knowledge representation. In terms of contribution to SDG 4.7 more specifically, the variety of media available can offer activities that can contribute to changing perspectives and cultivating empathy (see, for example, Farber and Schrier 2017 for digital games). Digital storytelling, whether individual or collaborative, could allow learners to explore complex political issues through personalised reports, picture stories, works of art and so on (Engagement Global 2018). Digital media offers considerable potential to get "closer" to others: from movies to direct communication; from music to simulations.

(4) Recursive Feedback

While there may be varied positions on the most desirable type of and time for feedback, there is fair level of consensus among educators that feedback is essential for learning. Widely prevalent regimes of summative assessment offer retrospective and judgmental perspective of learning, which mostly do not contribute to learning in prospective and constructive ways. However, technology-enabled learning environments and digital educational resources offer various opportunities for both feedback and feed-forward, supporting learners during their learning journeys.

As one option, digital games can be used for providing feedback. For example, in addition to assigning additional materials for individual students, BrainPOP offers SnapThought, as its game-based formative assessment. This qualitative reflection tool allows students to take a screenshot of gameplay and answer a question about why they made certain decisions. BrainPOP also offers "playful assessments"—assessments which are continuous and seamless, something between a game and a quiz. One playful assessment is Sortify, in which students choose a topic, label bins or

baskets, and then sort out image-adorned icons to where they belong. It looks like a game: there is a score and points with each bin. And it feels game-like.

Feedback mechanisms may take multiple forms — explicit summative format as well as scaffolded formative assessment around regular student learning activities. Feedback can also be designed for time-appropriateness such as real-time, just-in-time, and periodic. These affordances have engendered newer perspectives on formative assessments or assessments for learning rather than of learning. In this genre of assessments learners are encouraged to learn from mistakes. As anyone who has been a teacher knows, it is not always enough to simply say that a student has answered wrongly or made a mistake. Rather, the student needs to be supported with scaffolded help and encouraged to retry. Techniques such as making thinking visible, whether in analogue or digital states, may aid teachers in providing such 'just in time' feedback.

Further, with digital technologies and new media, an entirely new genre of *learning data analytics* has arisen which offers interesting insights for learning and learner modelling (Cope and Kalantzis 2016). While learner tracking and data-based profiling are contentious aspects of these developments, at least in their current phase of evolution, this does not detract from the potential of the technology to support appropriate feedback mechanisms. As such, the traditional distinction between formative and summative assessment may become blurred. Summative assessment may come in the form of progress visualizations based on data that was in the first instance formative feedback. In this area, there is enormous potential for the application of AI in education (Cope and Kalantzis 2019; UNESCO 2019b, 2019c, 2019d).

Recursive feedback also contributes to the notion that every child's learning can be supported by an individual learning path. With recursive feedback, teachers can help students to find their own way. When it comes to peer reviewing and peer-to-peer learning students can experience collaborative learning while they help each other. In this way, they learn to communicate in a cooperative way and so acquire knowledge through a process of participation in a knowledge community.

(5) Collaborative Intelligence

As reflected in the metaphor of learning as knowledge acquisition, education has tended to focus on learning as individual memory. Not to discount memory, knowledge and learning are social, as captured in participation and knowledge creation metaphors (see **Box 4-4** for discussion of the metaphors of learning). Knowledge has social provenance which requires acknowledgment, and social learning can be a powerful, indeed for today's society, an essential supplement to individual memory work — working with peers, offering and receiving feedback, and undertaking collaborative learning activities.

Indeed, human cognition is best understood and approached as a phenomenon intrinsically social that is rooted in interaction. Education becomes a matter of nurturing the networked nature of knowledge and learning in order to utilize it more efficiently and effectively toward aims that are inherently social. Digital environments provide concrete manifestations of collaborative knowledge networks to promote opportunities for and reflect back the work of collaborative intelligence. Educational environments of collaborative intelligence foster dynamic opportunities for learning communities to collectively create, refine, and share knowledge products that embody more authentic processes of human learning.

Opportunities to collaboratively construct unique pathways to accomplish learning goals are important for both learners and teachers. The rise of web-based social networking has enabled

learners and teachers to organize learning collaborations at all levels, purposes, and group sizes. Learners are no longer restricted to forming collaborations with just their peers in a course. They can organize inter-institutional collaborations, discover content, and participate in other learning communities to augment their learning. For example, a discussion paper on ESD and Digital Education in schools developed by German ESD experts (Engagement Global 2018) notes some pedagogical possibilities for ESD opened up by digital technology, including extending discussions on local and global issues beyond the classroom into the virtual diversity of social networks, blogs, portals and other communication channels and enabling joint teaching between German schools and partner schools in the Global South via video conferencing or Skype.

(6) Differentiated Learning

Differentiated learning refers to tailoring a teaching resource to a learner's needs and interests, with recognition that not everyone learns in the same way. Differentiated learning pays attention to diversity in the approaches and levels of students' needs. It offers every student the opportunity to find his or her own way into better understanding the world around. Sometimes, differentiated learning comes in the form of 'personalized learning,' however at times this can mean learning where individuals are isolated from each other (also see Section 2.2 in this chapter). Another, more collaborative version of differentiated learning we would call 'productive diversity,' leveraging the different interests and perspectives of learners as they work with each other — in 'jigsaw' learning, peer review, and discussion boards, for instance, where differentiation opens expression of learner diversity and deploys this as a resource for learning.

Digital learning platforms make differentiated instruction more feasible. Adaptive and personalized learning enables students to work at their own pace. While self-organisation helps students to organise themselves also in term of getting into action and organise not only their own learning but also learn to organise projects.

In digital learning environments, student voices can also be heard, in all their diversity (also see the active knowledge making affordance and multimodal meaning affordance). The social literacies and interpersonal skills learned in this context support student's capacity to negotiate deep diversity and navigate change. This enables learners to engage in difficult dialogues, learn to compromise and create shared understandings. In these ways, students will be able comfortably to extend their cultural and knowledge repertoires into new areas. They will learn to express themselves and learn to communicate with others and become tolerant, responsible and resilient in their differences.

(7) Metacognition

Metacognition or thinking about one's processes of thinking is a means to think more deeply, and at a higher level of abstraction (Livingston 2003). It produces efficiencies in thinking and learning, as conceptualization broadens the scope of ideas in application, transfer and understanding. Thinking about thinking is a valuable activity for online learners which leads to active learning (Huffaker and Calvert 2003). Thinking is also more efficient and effective when accompanied by the process of metacognition or monitoring and reflecting upon one's own thinking. An integral part of this process is weaving between the new knowledge and self-reflection about one's own knowledge background and thinking processes (Brown 1987). This requires interpretation of the social and cultural context of an expression of meaning or a piece of knowledge.

A basic and important aspect of metacognition is conscious awareness and regulation of cognitive strategies and processes to augment one's own thinking and learning (Pressley et al. 2010; Fernandez-Duque, Baird and Posner 2000). To achieve this, individuals need to be able to perceive, evaluate and regulate both attention and emotion. Recent evidence from cognition science shows that explicit instruction in social and emotional learning empowers students to regulate attention and emotion (Durlak et al. 2011). Specifically, training in mindfulness assists students to build conscious attention and awareness that can assist in the process of metacognition (Moore and Malinowski 2009). Similarly, an essential aspect of social and emotional learning, like that of emotion regulation, facilitates the promotion of both pro-social behaviour and an active control of thinking.

Metacognition crosses a range of socio-emotional and epistemological concerns (Hofer 2004). In socio-emotional terms, metacognition involves self-regulation and self-efficacy, or capacities to take control of learning and knowledge processes by being conscious of their required moves and actions (Flavell 1979; Brown 1987). In epistemological terms, metacognition refers to disciplinary practice — consciously thinking like a scientist, a literary critic, historian, and such like. Such metacognition involves theoretical thinking and supports transfer of learning from one empirical domain or social context to another.

This is possible and facilitated through digital technologies which allow learners to think about their own thinking as they reflect on what they have learned. Through specific pedagogies like self-assessments, surveys, quizzes, journals, posts and reviews learners are able to determine areas of weakness, strength as well as potential areas that might be of interest.

Metacognition in all its different shapes is core to understanding the complex issues of sustainable development and developing ideas and actions to meet those challenges. So, metacognition means to learn critical thinking and understanding complex systems. This is necessary in order to find solutions to complex problems. Understanding complex systems has to be the first step in order to make change in the material and social conditions of life.

(8) Accessibility

Accessibility refers to the availability of digital educational resources to all, irrespective of geographic location, language(s), disability and other demographic and socio-economic variables. Educational technology as a cognitively dis-embodied *thing* posits both limitations and opportunities. On the one hand it may extend the *action space for learning,* while on the other hand it may impose new barriers. These traits are fundamentally shaped by the *design* of technology. Therefore, it is imperative to ensure that digital educational resources are designed to extend the *action space for learning* — the key to doing so is make them accessible. In terms of SDG 4 to ensure "inclusive and equitable quality education and promote lifelong learning opportunities for all", the affordance of accessibility is a matter of promoting openness and inclusion.

In this context, accessibility of digital educational resources has three primary dimensions. The first dimension is to promote the availability of digital educational resources. There are two ways in which this might be achieved. The first is for education systems to ensure that there are no barriers to access based on the cost of published materials and digital resources. Producing materials has a cost, and education systems have exploited the availability of supposedly "free" resources to reduce their costs. The problem is that "free" comes at a cost—the cost of giving user data away to companies in order for them to build user profiles for the purposes of advertising. The second is free and open source digital resources. However, the challenge here is to offer proper remuneration

for creators, traditionally taking the forms of author royalties and employment in the educational publishing industry.

The second dimension is interoperability, which requires that the system is open to different kinds of expression, and integration with other (external) tools and systems (see the indicators 8.3 and 8.4 of Table 1 in **Appendix II**). Complying to interoperability standards allows aggregation of efforts, integration of systems, and opening of learning opportunities.

Third, it is important to follow Universal Design for Learning (UDL) principles to ensure that learning resources are accessible to all, including people with disabilities. It is also important to ensure accessibility of resources across a range of devices, in online as well as offline mode. Provision for translations and internationalization of interfaces is another key consideration.

These three dimensions are also significant from the viewpoint of ensuring freedom of expression and universal access to information and knowledge (UNESCO 2017). The issue of copyright and ownership needs to be addressed explicitly in order to help students understand the Janus-faced character of digitalization so they might contribute to shaping technology in a way aligned with peace and sustainable development.

3.2 Potentials and limitations of the 8A framework

Digital educational resources could pave the way to cultivate innovative ways of teaching and learning. The 8A framework can be useful for product designers and policy makers to help in choice and development and for practitioners to think about what they can implement in the classroom.

When digital educational resources are thoughtfully designed, developed, employed and adopted, they have the potential to foster active pedagogies and support learning to achieve the goals of education for sustainable development. The 8A framework may be used as a heuristic by:

- Policy makers - to decide on curricular frameworks and digital resources;
- Peachers - to seek, select and develop digital resources;
- Publishers - to expand access, develop relevant and efficient resources and ecosystems; and
- Academics - to review, evaluate and further the educational possibilities of digital resources.

At the same time, as we have repeatedly pointed out, educational resources, digital or otherwise, do not by themselves guarantee any substantially effective learning outcomes. Learners can exercise their imaginations and 'produce meaning' by reading a good book. Curious learners can also pursue their various learning pathways at their convenience by using a decent school library, and in a more structured way. It is therefore important to keep in mind that the 8A framework is simply a heuristic and neither justifies 'going digital' nor denounces non-digital resources.

Furthermore, we do not know if some of the affordances are always perceived and experienced positively. For example, the ubiquitous learning affordance allows formal learning to break out of the spatial and temporal confinement. While this can liberate learning from past conventions, it can also be experienced as all-pervasive and oppressive. School-community interactions facilitated with digital technology can be experienced as stressful and intrusive – by teachers, children and parents. By virtue of powerful ways of representation associated with the multimodal meaning affordance, digital technology can arguably foster a mindset of instant gratification, short attention spans and, superficial engagement with ideas. The 8A framework is not an evidence-based framework, and as this chapter has shown, much research is needed to understand the relationships between

digital technology use and learning. It should also be noted that it is a generic framework for digital learning and does not take into account different affordances of different types of digital media and resources.

Box 4-6 presents a case of the Connected Learning Initiative (CLix) from India to illustrate some of the affordances through concrete examples. It also provides some information on implementation of CLix, but it is difficult to tell what kinds of challenges the initiative has encountered or what kind of impact it has had on users so far. The efficacy of educational resources can be circumscribed by factors external to the resources such as teachers, the wider education system, and cultural milieu. The next section therefore focuses on implementation and use of digital educational resources.

Box 4-6 The Connected Learning Initiative (CLIx) in India (by Sadaqat Faqih Mulla)

"The Connected Learning Initiative (CLIx) is a technology enabled initiative at scale for high school students. The initiative was seeded by Tata Trusts, Mumbai and is led by Tata Institute of Social Sciences, Mumbai and Massachusetts Institute of Technology, Cambridge, MA, USA. CLIx offers a scalable and sustainable model of open education, to meet the educational needs of students and teachers. … Resources for students are in the areas of Mathematics, Sciences, Communicative English and Digital Literacy, designed to be interactive, foster collaboration and integrate values and 21st century skills. These are being offered to students of government secondary schools in Chhattisgarh, Mizoram, Rajasthan and Telangana in their regional languages and also released as Open Educational Resources (OERs). Teacher Professional Development is available through professional communities of practice and the blended Post Graduate Certificate in Reflective Teaching with ICT. Through research and collaborations, CLIx seeks to nurture a vibrant ecosystem of partnerships and innovation to improve schooling for underserved communities."[102]

CLIx is a large-scale intervention that aims to demonstrate how quality of education can be improved in India through thoughtful use of technology. It offers 15 modules containing more than 200 hours of learning content in the subject domains of Digital Literacy, English, Mathematics, Science, and Values Education in English, Hindi and Telugu languages. Between years 2016-19 the initiative has reached to 478 public schools across four states of Chhattisgarh, Mizoram, Rajasthan and Telangana. More than 47,526 students in Grades 8 and 9 have used these modules. The intervention is in active implementation phase since 2016.

Key features include the following:

1. Interactive learning platform with rich multimedia content
2. Simulations and gamification
3. Formative assessments
4. Multiple concurrent login to foster collaborative learning
5. Multilingual support
6. Ability for teachers to create their own content
7. All content is released under CC-BY license, free and open source software
8. Online and offline availability

The CLIx modules are "thoughtfully designed" media rich interactive content hosted on a learning platform to leverage the potential of ICTs for meaningful learning opportunities. The design of content is underpinned by three pedagogical pillars - collaborative learning, learning from mistakes and authentic learning. The modules comprise of select concepts from prescribed curriculum

102 https://tiss.edu/view/11/connected-learning-initiatives-clix/

and act as exemplars to complement the regular chalk-board teaching. Students' and Teachers' handbooks are provided on the platform for ready reference.

The learning platform and modules offer various affordances from 8A model albeit with varying degrees. It offers exemplary levels of affordances for active knowledge making, multimodal meaning making, collaborative Intelligence. With the use of auditory, visual and kinesthetic artefacts, simulations and games the CLIx modules offer multimodal representation of concepts and thereby encouraging deep learning. The modules also expressly allow interactivity and encourages construction of artefacts by students through peer collaboration. There are role play activities and games that require partners and the platform itself has a buddy login feature that on the one hand addresses the high student-to-computer ratio and on the other hand it helps to cultivate collaborative skills.

Through the lens of the 8A framework, CLix has moderate level of emphasis on recursive feedback and metacognition aspects of learning. While the feedback mechanism is available on the formative assessment components, on the overall learning progress there is no such feedback available leaving learners to take their own course of action. The accessibility or openness aspects are purposefully addressed with all the content released under creative commons attribution license and the platform software release as free and open source software. It also integrates various other open educational resources such as TurtleBlock and PhET simulations and demonstrates a best practice model for developing ICT tools in an integrated manner.

URLs: https://clix.tiss.edu/ ; https://demo-clix.tiss.edu

4. Where Are We and Where Are We Going from Here?

While there is certain appeal to the notion of 'digital pedagogy', we should not rush to embrace whatever is digital as positive and progressive. Instead it is useful to view learning and teaching as 'social instrumented activities', taking place within institutions having goals and values or in informal contexts. The three words — 'social', 'instrumented' and 'activity' — are important. Activity because it requires action (and listening is an activity); social because we learn with others, not alone, and with the help of persons playing the role of tutors, teachers or peers; instrumented, because simple oral instruction is typically not sufficient and we often use technologies, including books and textbooks, notebooks, blackboards, whiteboards, computers and other devices, both simple like Freinet's teaching box and highly elaborate like augmented reality equipment.

Digital technology mainly provides new instruments and new activities or transforms existing activities. It opens up new opportunities for learning and teaching, while it can also obliterate other existing opportunities — which in turn generates the need to design new educational activities. Digital technology also has a strong social impact, changing many aspects of our life, sometimes modifying how we relate to knowledge. Many young students may well wonder if it is still useful to study something when Google can give an answer to any question.

The concluding section of Chapter 3 noted an important shift from a situation where educational resources were scarce to a situation of abundance. Some further reflections on a new context of abundance are needed to better understand where we are now and where we are going from

here. Although this situation of abundance is far from universal, the context of abundance itself is not so new in many countries. For example, more than half a century ago, Freinet (1964a) wrote that "[the] sources of knowledge have multiplied to the extreme, to the point of becoming invasive", referring to newspapers, radio, cinema, television and travel. He further argued:

> *Practically, we have nothing more to teach our students, they have seen and heard everything. But this excess itself is at the expense of the depth of this knowledge. The child does not know the elements, causes or consequences of what he or she sees. … Better still, this excess knowledge will capture some of the functions of intelligence at the expense of those that once influenced people's behaviour and understanding. We are in an era where an excess of knowledge tends to block understanding and culture.*
> (Freinet 1964a, translation by the editors)

Today, some commentators would make exactly the same points Freinet made above. Two phenomena, however, take the context of the multiplicity of knowledge sources to a whole new level that requires considerations that go beyond concerns about information overload and shallow engagement with knowledge. The first is the convergence of technologies around digital, which enables the same devices to manage text, image, sound, videos, games and data. The second is the spread of the mobile phone as a pivotal instrument, the one around which almost all activities are organised, with direct access without intermediaries. What are the implications of 'disintermediation' in access to knowledge and the emergence of large platforms enabled by digital technology?

The smartphone is a tool for direct connection to a digital platform and for disintermediation. Partly inspired by successful cases where digital technology helps businesses bypass intermediaries to connect directly to customers, some advocates of digital education have called for 'disrupting' education by getting rid of teachers and schools. Online repositories, platforms and LMSs can provide ready access to education resources and act as effective intermediaries, complementing and partially replacing the work of teachers. Nevertheless, aside from the question of desirability of getting rid of human mediation in education, it is deeply problematic to equate teachers as intermediaries in an economic transaction. On one level, it raises a question whether it is appropriate to compare education to service industries, characterize students as consumers and customers, and treat knowledge as a commodity. On another level, calling for the removal of teachers in the spirit of 'cutting out the middlemen' and reducing costs seems to reflect the denigration of teachers as mere 'delivery technicians' stripped of professional judgment and autonomy. Furthermore, as Timeline 3 shows, with the double movement associated with the emergence of large digital platforms, we are simultaneously witnessing the unprecedented possibilities for openness and participation as manifested in an open education movement on one hand and for the reinforcement of control and surveillance as reflected in the concerns for privacy and data protection on the other.

All these considerations point to the importance of containing our excitement with promises of going digital. What really matters is to use paper and digital education resources in a way that meets the needs of educators and learners without compromising human rights and fundamental freedoms and the goals of sustainable development. With the increasing penetration of digital products, coupled with shortening product cycles, especially those of smartphones, discussion of digital learning should not avoid the serious problem of 'e-waste', which is toxic and harmful to human health and the environment, particularly when poorly managed (Mcalister and Horan 2017; Moletsane and Venter 2018). As much as large digital platforms with the application of AI can calculate and propose some learning paths to follow, pedagogy fundamentally remains a human activity — which can benefit from what technology offers and should be guided by a vision of learning aligned with the aspiration of advancing well-being for all, including human and more than human life and current and future generations.

CHAPTER 5

Implementation and Use: Case Studies

The current and potential future transformations associated with digital technology are multi-faceted and affect many dimensions of education. It is beyond the scope of this report to discuss them all in depth. There is a rapidly renewed and expanding supply of resources that support a range of pedagogical approaches. These are circulating in very different educational systems and amongst a diverse set of actors including administrators, teachers, policy makers, inspectors, parents, students, and other stakeholders in the private and civil society sectors. How can complex, functioning education systems take into account the new instruments associated with digital technology, whether textbooks or digital educational resources?

The previous chapters have made it possible, based on a review of literature on the use of technology in education and a historical look at educational resources, to present the emergent definition of digital textbooks and digital educational resources and an accompanying set of examples. We also explored pedagogical possibilities opened up by digital technology. After studying digital products (Chapter 3) and the pedagogies they can support (Chapter 4), this chapter draws on several case studies to present how these products and their pedagogies can be implemented in schools and in other settings. It focuses on specific uses and exactly what makes these uses possible.

Instruments, Actors and Systems

The introduction and rapid spread of networked digital devices — computers, tablets and smart phones that connect us with one another as well as with a wealth of content and various digitally-mediated interactions such as games — have contributed to overcoming the physical constraints of schools. Spatial, temporal and material constraints such as four walls of the classroom, school timetables, and the need for the teacher to teach the same content to a group of students at the same time can now be transcended, at least technologically (if not administratively) where certain conditions are met. Digital resources and digital learning environments are sometimes presented as the triumphant embodiment of learner-driven pedagogy and personalized learning, which makes mediation by teachers — or the very existence of teachers — unnecessary. Perhaps the most well-known example reflecting such idea is the "Hole in the Wall" experiments in India initiated by Sugata Mitra.[103] These experiments supported Mitra's idea of "minimally invasive education", which is defined as "a pedagogic method that uses the learning environment to generate an adequate level of motivation to induce learning in groups of children, with minimal, or no, intervention by a teacher."[104]

However, such discourses that categorically cast teacher intervention in a negative light neither reflect realities of the use of technology for educational purposes nor help harness the pedagogical possibilities opened up by digital technology. Mitra himself shifted away from "Hole in the Wall", and now runs the "SOLE (Self-Organized Learning Environment)" project designed to support self-directed education in traditional school settings with much more focus on the role of mentors and guiding questions (Dolan et al. 2013; also see Dron and Ardito 2018). As Richard Mayer (2004) showed by reviewing over 30 years of research on discovery learning, there is sufficient research evidence to support that guided discovery is more effective than pure discovery in helping students learn. Mayer (2004, p. 14) concluded that "the constructivist view of learning may be best supported by methods of instruction that involve cognitive activity rather than behavioral activity, instructional guidance rather than pure discovery, and curricular focus rather than unstructured exploration". For the foreseeable future, the value of teachers as expert facilitators of learning and socio-emotional development is unlikely to be displaced by technology. While exploring the potential of digital technology in transforming education, it is also important to be fully cognizant of the long-observed trend where a passion for new technology turns into teacher-bashing (Cuban 1986; Cuban and Jandrić 2015) and the reality of the modest use of technology in schools reported by studies in the United States (see **Box 5-1**).

Box 5-1 Still 'oversold and underused': Low usage of software purchased by school districts in the U.S.

In his influential book *Oversold and Underused: Computers in the Classroom*, Larry Cuban (2001) observed that teachers used computers in the classroom only occasionally in unimaginative ways — when they had not been given a voice in how technology might change school and classroom practices and enhance learning. After almost two decades, a special report published in *Education Week* in October 2019 confirmed the long-observed trend of the relatively modest use of technology in schools and classrooms (Klein 2019).

The special report covered two studies released by BrightBytes, an education data-management and analytics platform, and Glimpse K12, an EdTech company. BrightBytes observed in its report released in November 2018 that most software licenses school districts buy go unused.[105] The

103 Dron and Ardito (2018) cited Sugata Mitra's Hole in the Wall project as an initiative that exemplifies "connectivist" thinking.
104 http://www.hole-in-the-wall.com/MIE.html
105 https://www.brightbytes.net/resources-archive/insightsreport2018

analysis — based on a dataset from 48 school districts serving more than 390,000 students and 177 browser-based online tools — found that a median of 30 per cent of EdTech licenses are never used and 98 per cent of licenses are not used intensively. Similarly, a 2019 study by Glimpse K12 found that 67 percent of educational software product licenses never get used, tracking 200,000 curriculum-software licenses purchased by 275 schools in 2017-18 which amounted to two billion US dollars in school spending. The analysis identified educational software as the biggest source of wasted spending in K-12 districts, estimating that districts are suffering an annual loss of two million dollars each on these products.

While innovative uses of technologies exist and are frequently given as examples, significant developments occur only where conditions for immersion in a favourable environment are met, facilitating the acquisition of equipment and the implementation of stabilized operating modes. A single unified model of how education systems should best take advantage of digital technologies is currently unavailable since their effective use depends on contextual, political and ideological choices. Therefore, in this chapter, several case studies were chosen to explore some key issues emerging from this highly variable process of transformation. To organize these case studies, we use a theoretical framework associated with research on the deployment of digital resources in education, the **Instrument–Actors–Systems** framework (Baron and Bruillard 1996).

It is the ***actors***, the users of technologies, who take the various initiatives that enable these innovations to take hold, whether locally or more broadly. They are critical in enabling the diffusion of digital technologies in regular schools — outside of places specialized in innovation. Their role is decisive in making digital technologies work for educational purpose.

Technology integration in education raises questions about change management problems in social organizations governed by codified rules. The ***instruments*** are implemented by lay people (students), under the direction of teaching professionals who prescribe legitimate and effective methods of use, according to institutional requirements (such as the programme and the curricula) and incentives provided by different bodies. Both teaching professionals and incentive providers (often researchers and EdTech companies) have views, beliefs and value judgments that guide their actions. In addition, they operate within ***systems*** that offer them margins of manoeuvre and constrain their action (Baron and Bruillard 1996).

We therefore have to consider the interactions between systems, instruments and actors. Merely discussing ‘digital products’ and ‘digital pedagogy’ — often advertised as ‘evidence-based’ products and pedagogy — is as pointless as the attempt to describe muscles or internal organs without a reference to the living body within which they exist and function, and to improve their functions without a reference to the person’s lifestyle and overall well-being.

1. Instruments

For the **instruments** or products, we will take only one example, Minecraft, a videogame which has caught attention of educators and researchers across the world. For what purpose is it used in education, but also how can it be used?

There is a substantial interest in computer games in educational settings, as manifested in scientific research on instructional effectiveness of computer games (Mayer 2019) as well as political initiatives going far beyond the personal interest of individual teachers using games in their

classrooms. For example, European Commission's Working Group on Digital Education organized its first peer learning activity in January 2019 and explored various Digital Game-Based Learning approaches (European Commission 2019).

On one hand, there are games that have been designed specifically for educational purposes and they are often referred to as educational games. On the other hand, there are many commercial (off-the-shelf) games such as Civilization III, Making History, and Sim City 2000, which have been used in education. Minecraft celebrated its tenth anniversary in 2019. More than 176 million copies — including all editions such as mobile-specific edition — have been sold by May 2019 in virtually every country in the world, while Minecraft China, a free-to-play version of the game distributed by NetEase, surpassed 200 million players.[106] Minecraft was originally developed as an off-the-shelf game, and Minecraft Education Edition was designed specifically for classroom use and launched in 2016.

Nebel, Schneider and Rey (2016) have reviewed the literature on use of Minecraft in education and experimental research, summarized its current usage, and discussed its benefits and limitations. Minecraft is in use as an educational tool for very different topics, including spatial geometry for class level 5/6, sustainable planning, language and literacy, digital storytelling, social skills, informatics, computer art application, project management, and chemistry; further topics teachers want to address include ecology, geology, biology, physics, geography, arts, history, media industry, and AI (Nebel, Schneider and Rey 2016, p.357). Furthermore, Minecraft is also used for peace education. Games for Peace[107], an Israeli NGO, explores the use of video games as a platform for trust building in conflict zones. It uses Minecraft to promote trust, tolerance and dialogue between Jewish and Arab Schoolchildren. In their programme, children from two schools — one Arab and the other Jewish, play Minecraft together from their schools' computer rooms, in a specially crafted series of virtual encounters designed to gradually increase the level of communication and collaboration. Eventually, the children in these two schools meet face to face and learn they are far less different than they thought.

This clearly speaks to the broad applicability and pedagogical appeal of Minecraft. Although the success of Minecraft is indisputable, the use of Minecraft in French lower-secondary (Grade 6 and 7) classrooms detailed in the following case study (**Box 5-2**) presents some of the constraints of its pedagogical use, based on classroom observations and student and teacher interviews.

106 https://www.pcgamesn.com/minecraft/minecraft-player-count
107 http://www.gamesforpeace.org

Box 5-2 The pedagogical use of Minecraft: Which constraints to overcome? (By Christelle Pauty- Combemorel)

Research on the educational use of *Minecraft* has focused on capturing its pedagogical potential by identifying its main contributions both in increasing student motivation and in learning disciplinary concepts. Although it may contribute positively to the relationship between learners and school work in some situations (Nebel, Schneider and Rey 2016), our analyses indicate the existence of usage constraints that would result from the operation of such software in the school context.

The first constraint is material. The pedagogical use of *Minecraft* requires computer equipment connected to the school's Internet network, although some teachers bypass possible connection problems that may arise by using their personal server to facilitate student activity. In addition to the difficulties associated with purchasing and installing the software on workstations, the game is written in Java and licensed under a proprietary license. This means that it is impossible for the teacher to access its source code to understand how it works or to modify it in order to customize the game.

The second constraint is related to youth practices. Indeed, many teachers rely on the playful practices of young people in video games by choosing to use *Minecraft* in class. It is interesting to recall that it is marketed on a wide variety of media (computer, smartphone, Xbox, PS3 and 4, Wii U, Nintendo Switch and 3DS). The students' experience and skill development may be influenced by the equipment they use and whether the interface is through mouse and keyboard, game controller, a touchscreen or a joystick. The context of personal use may facilitate or hinder the appropriation of this software in the classroom.

The third constraint is technical-pedagogical. This could partially explain the teachers' choice to use the "creative" mode to overcome the constraints related to the game itself. In "survival" or "hardcore" mode, it is essential to build a "house" at the beginning of the game to protect yourself from antagonists who only appear after dark. This requires time and manipulative skills. In the "creative" mode, all you need to do to use a torch is open your inventory and select the object. It is not necessary to use the "crafter", i.e. to make it by combining a stick and a piece of coal. While this could reduce students' trial and error times, it is still essential to give meaning to learning by framing and explaining it.

Beyond understanding how this game is appropriated for educational purposes, it is important to look at how teachers and students approach the use of this game in the classroom based on their own experiences as players. The latter could be decisive in understanding how they appropriate it in teaching-learning processes.

Finally, my observations suggest that it was the teacher's presence on Minetest (Minecraft's free alternative) that gave meaning to school work. One student said: "*When you are on line with the teacher, it is work because it is the same objective as in class, whereas when you play a survival game alone, then you play*" (Marius, grade 6 student, 2016).

2. Actors

For the **actors**, we will focus on teachers, not as individuals, but as a collective (see **Box 5-3**). The increasing complexity of education, including the volume and constant renewal of knowledge and skills to be taught, place a very heavy burden on the shoulders of each individual teacher. Hence a collective vision of the teaching profession becomes all the more important. Although it goes beyond the scope of this report, other actors would have to be studied to develop a comprehensive understanding of the use of digital education resources in education systems: education inspectors and various other officers in the education department, people working in educational administration, parents, and most importantly, students themselves.

Before presenting a case of teacher collectives, we introduce an important strand of research from France relating to teachers and educational resources.[108] ***How and why do teachers select, modify, revise, share, and discuss educational resources?*** These activities are routinely performed by teachers yet are poorly documented as such work is often carried out informally and outside schools. However, this question has become increasingly important in thinking about educational resources in recent years due to various new contexts, such as the emergence of new areas to be taught and the need to ensure multiple views of the same subject area. These new demands are being driven in part by the ongoing transition from paper to digital resources, the diverse forms of hybridization between analogue and digital objects, the rapid spread of digitized infrastructure, and the explosion of individual use of digital resources. One can only understand educational resources by understanding the work of teachers and the communities of teachers that support and sustain them.

Another important topic is turnkey or ready-to-use resources. Many believe that teachers should be provided with resources that they can use directly without any modification. This is contrary to the most common practices of teachers who remain end-of-pipe adapters of educational resources. Indeed, adaptations are generally necessary to match: (1) the prescribed programme parameters (official curriculum); (2) the variable level of individual students, classes, and cohorts; (3) the pedagogical progression followed; and (4) the teacher's habits, preferences, and the philosophy of education. In addition, there is a need for appropriation and re-appropriation so that the teacher can have a thorough knowledge of the proposed content, can answer students' questions, and make links with other concepts. Of course, ready-to-use resources can be useful for beginners who need first models to follow, for new curricula or for those who are not familiar with the subjects they teach. However, this is typically a first step and, with experience, many teachers adapt off-the-shelf resources to suit the specific needs of the context. Finally, the faults of ready-to-use resources can be criticized to deepen student understanding of certain concepts by the teacher or students themselves, or used creatively by the teacher as a point of reference to guide discussion in the classroom. This suggests that even poorly designed resources can be used in a way that supports active pedagogy, underscoring the importance of teachers as actors.

108 See various publications on the website of the EDA laboratory at the Paris Descartes University: http://eda.recherche.parisdescartes.fr/educational-resources/

Box 5-3 Living learning resources: Resource sharing among teacher collectives (by Aurélie Beauné and Éric Bruillard)

Teachers: resources producers in changing conditions

A central task of teachers' work is to design, research, select, modify, and recompose the resources in a way that can be presented to their students so that they serve as a basis for teaching and learning activities. This teachers' work on resources is constantly evolving, in line with changes in curricula or high-stakes examinations, but also according to the available technologies and the concomitant development of new pedagogies such as the spread of 'flipped' or 'inverted' classroom environments as digital Learning Management Systems became commonplace.

Textbook publishing is also changing: many jurisdictions are abandoning pre-approval commissions. For example, they were abolished in Norway in the early 2000s. In California, since 2012, Creative Commons licensed textbooks, designed by state universities, have been made available to students through a resource library, also developed by the universities in open source[109]. In France, several disciplinary associations and collectives of teachers[110] have designed and distributed widely used digital textbooks: for example, since its creation in 2000, the digital textbooks produced by teachers, members of the Sésamath association, have been so successful that it has come to compete with traditional publishers, quickly winning nearly 15% of the market (Quentin and Bruillard 2013; also see Box 3-1). In addition, Sésamath offers complementary exercises that can be performed by students on remote platforms, and teachers can easily retrieve the results of their own students, giving a convincing example of an open digital textbook over the past ten years.

For several decades, the development of the uses of digital media has led to changes in teachers' work, particularly with regard to the sharing and diffusion of OERs. For example, Norwegian Digital Learning Arena (NDLA)[111] is a project initiated in 2007, aimed at collaboratively designing and disseminating free and open educational resources of good quality and whose evolution would be continuous, in secondary school subjects. As well as a means of generating and disseminating context appropriate resources, a stated objective is to contribute to the development of a culture of sharing within upper secondary education in Norway.

In her thesis work on the exchange of educational resources in secondary education in Vietnam, Thai N'Guyen documented the factors that favour and hinder the sharing of resources among teachers: the first obstacle concerns the lack of confidence of teachers in their own production; then comes the lack of time, the lack of tools and skills in their manipulation, copyright and recognition issues, a lack of a culture of sharing, with sometimes the will to keep documents rare because of competition between teachers. Factors that promote sharing include incentives, having quality, easy-to-use resources, and trust within teacher groups with access to discussion features in their sharing sites (Nguyen and Bruillard 2011).

The study of teachers' work on their resources was at the heart of the ReVEA or Living Resources for Teaching and Learning (2014-2018) project[112]: educational resources are alive, not by their own characteristics, but by the work of teachers and the communities of teachers who make them live. In other words, educational resources can only be understood by studying how teacher collectives make them work.

109 California Open Educational Resources Council, http://icas-ca.org/coerc; http://www.theatlantic.com/technology/archive/2012/09/california-takes-a-big-step-forward-free-digital-open-source-textbooks/263047/

110 These collectives can correspond to non-profit associations but also to businesses; see for example: https://www.lelivrescolaire.fr/

111 Norwegian Digital Learning Arena (Nasjonal digital læringsarena): http://om.ndla.no/about-ndla. Subsidized by the counties (regions) and not by the State, NDLA is part of the Nordic network of open educational resources: http://nordicoer.org/english/

112 https://www.anr-revea.fr/ Bruillard (2019).

Numerous, diverse and productive teachers' collectives

The development of various forms of teacher collectives has been observed and documented in many countries. The contrasting analysis of 52 studies of formal and informal online teacher communities shows the importance of social web technologies in supporting teacher collectives: "while formally-organized and informally-developed communities address different needs among teachers and support different outcomes, they also share several common characteristics. Indeed, regardless of type, online communities can be a valuable means of developing supportive and collegial professional practices"(Lantz-Andersson, Lundin and Selwyn 2018, p.303).

A study of disciplinary collectives of online teachers was carried out in depth by Quentin (2012), highlighting two main models of organization: the *hive model* refers to collectives whose organization is based on very precise rules and strong shared values (Sésamath and APSES[113] are two characteristic examples); the *sandbox model* refers to collectives whose organizational rules are flexible, allowing the sharing, dissemination and legitimization of teaching practices.

Santana Bonilla and Rodríguez Rodríguez (2019) identify four types of educational web portals: "institutional portals set up by an educational administration; teacher networks portals which contain materials elaborated by teachers and managed by different agents; portals not designed for formal education mastered by different agents; and commercial platforms operated by a publishing company". Access to the resources produced can be completely open, especially in the case of institutional portals and educational portals that do not necessarily concern formal education.

However, the unified analysis of the various forms of teacher collectives' activities (online or not) and their evolution, particularly with regard to the production of educational resources, is still in its early stages (Beauné et al. 2019). Some teachers' associations, close to the centenary and still active today, have been created in the international movement of New Education and Popular Education: what do they share with, for example, the flipped classroom movement, which is also of international scope?

With regard to the functioning of collectives created in the last decade, particularly those that develop their activities on social networks, several studies show that they rely on the influence of "personalities", praised by communities whose rules of participation seem mainly based on skills similar to those of communication professionals (Bergviken Rensfeldt, Hillman and Selwyn 2018; Beauné et al. 2019).

When considering the production of educational resources, it is important to make visible and to document the work of long-standing and emerging teachers' collectives. Existing research has highlighted the role of such communities in the professionalization of teachers (Lantz-Andersson et al. 2018). Teacher collectives constitute specific spaces for interaction on resources but also for sharing, appropriation and development of original proposals for the design and dissemination of living educational resources.

113 See for example: https://sesame.apses.org/

3. Systems

Finally, in terms of **systems**, we have several case studies from different continents. How can an education system organize the implementation of digital technologies?

First, the case from Hungary (**Box 5-4**) reports on findings of research on the use of e-learning tools in a formal education setting. A series of experiments conducted at a pilot school in Hungary shows that there are different uses according to the age of the students (older students make more creative uses of digital tools) and that the possibility of using digital resources at home (which requires that students have access to machines) plays an important role. According to research reported in the case study, long-term pedagogical transformations with digital devices are based on the creativity of teachers. Teachers participate also in the design of digital textbooks (Kojanitz 2019).

As we have seen in Chapter 3, Hungary has a centralised education system and offers a digital platform for teachers, students and parents called National Portal for Public Education (Nemzeti Köznevelési Portál, NKP) (see **Box 3-4**). However, what works in a country of 10 million people cannot work in a more populous state, whether centralized like China (**Box 5-5**) and France (**Box 5-6**) or less centralized such as in the cases of Germany (**Box 5-7**) and the U.S. (**Box 5-8**), where responsibilities are shared between the national and sub-national levels. The case studies from China, France, Germany and the U.S. therefore highlight some of the different issues to be considered.

Box 5-5 introduces a case of top-down digital education transformation in China. Even though 17zuoye (see **Box 3-3**) is a private enterprise, it has worked closely with the current school education system in two ways. First, it bases its online resources on the latest national curriculum. Through eight years of cooperating with education publishing organizations, it has transformed all versions of textbooks from offline to online. Second, it works with schools to tailor its services to different contexts, for example, by providing homework and assessment tools to primary schools or differentiated work for students at advanced levels, as well as other Online to Offline (O2O) services (Luo 2019). 17zuoye has a team of 500 locally based trainers across over 100 cities in the country who go to schools for targeted teacher training on demand, sharing of experiences and proposals, and feedback (Harbinger 2017).

Box 5-6 presents a combination of top-down and bottom-approaches to implement digital textbooks in high schools in one region in France. **Box 5-7** focuses on the federal strategy on education in a digital age in Germany, which calls for developing solutions to legal challenges of data protection, youth protection and copyright laws, in addition to technical and infrastructural challenges and challenges of quality control of digital resources. **Box 5-8** reports on how a decentralized, multi-tiered education system in the U.S. supports technology use, looking at federal, state and local level policies.

The next case study focuses on new states which came into existence following the disintegration of the Soviet Union. Aside from the need to build a sense of belonging in a new state through education, which is not discussed in this report, sustaining academic and scientific communities following social and political ruptures has posed a major challenge to Central Asian states. The case of the Central Asian Research and Education Network (CAREN) funded by EU (**Box 5-9**) provides an example of addressing the barriers to e-learning caused by slow and expensive access to the Internet, with a large-scale donor funding. **Box 5-9** raises questions around how to ensure a certain independence of national ICT infrastructure, including Internet access, which is central to digitalization of education.

While **Box 5-9** focuses mainly on the higher education level, the following two cases (**Box 5-10** and **Box 5-11**) present efforts to address barriers to accessing quality educational content in the K-12 context. Like CLIx in India introduced in **Box 4-6**, offline content delivery is one way to address access to quality educational resources in places where internet connectivity is unreliable. **Box 5-10** presents a case of SolarSPELL, a solar powered offline digital library deployed in the Small Island Developing States (SIDS) in the Pacific to address barriers caused by intermittent or cost-prohibitive access not only to the Internet but also to electricity in remote locations. SolarSPELL is a "ruggedized, portable solar-powered digital library over an off-line WiFi hotspot, designed to simulate an online experience", and to date more than 275 SPELL libraries have been implemented in the Pacific and East Africa.[114]

SolarSPELL provides a good case which addresses the basic digital foundation: (1) infrastructure and equipment, (2) the provision of educational resources (content vetted and verified as a reliable resource), and (2) teacher training (in this case, provided by U.S. Peace Corps Volunteers). If SolarSPELL is a bottom-up initiative which started out in 2014 as an Arizona State University student engineering project "to create a solar-powered library that would fit into a backpack"[115], the cases from Africa (**Box 5-11**) present top-down government initiatives: Kenya's Digital Literacy Programme and Uganda's Kolibri platform under the "Transforming Computer Labs into Learning Labs" initiative. These cases show how some governments use OERs to populate national digital learning platforms in an effort to ensure access to quality education resources. They also highlight the challenges of enabling open access using OERs in the primary and secondary education context in the Global South.

Together, these case studies illustrate that the use of digital technology requires the establishment of infrastructure, which is both a technical and a political problem. The development of such infrastructure takes place at a national or regional level and is dependent on the level of national economic and social development and the country's diplomatic, strategic, and economic relations with other countries. It is dependent on general principles established by the states, for example territorial equity (inter-school and inter-regional equity within the national territory) and the relationship between the private and public sectors, which have a powerful impact on the educational policies and strategies developed. What actually happens in classrooms is therefore directly related to these policies.

As well as the importance of infrastructure and guiding policy, the latitude for initiative that local stakeholders have in these decisions is a crucial consideration. How can we set up reliable infrastructure for all, yet leave enough autonomy with local actors? The cases of Kenya and Uganda illustrate the difficulty of linking the development of a local supply of educational resources with external options that may have been more or less adapted to meet local needs. To conclude this chapter, we draw attention to the central role of states in making digital equipment and resources available to education stakeholders.

The growing power of digital giants and their digital platforms (Google, Amazon, Facebook, Apple, Microsoft) allows them to offer attractive resources and infrastructure for education. But beyond the technical quality of these offers, how will states be able to maintain their independence in their educational choices for their citizens and future citizens? What should be the role of UNESCO in supporting Member States ensure that the use of digital technology in education contributes to shaping more peaceful and sustainable societies? This is an open question which demands open dialogue among diverse stakeholders.

114 http://solarspell.org/about
115 https://asunow.asu.edu/2019072-global-engagement-asu-professors-solar-powered-library-transforming-global-education

Box 5-4 Evolution of digital textbooks and school-based studies on their use in Hungary (by Péter Antal, Tünde-Lengyel Molnár and Réka Racsko, Department of Media Informatics, Eszterházy Károly University)

The Hungarian Institute for Educational Research and Development, which became a part of the Eszterházy Károly University in 2016, has conducted research to study e-learning tools for more than ten years. Since 2006, a series of school-based studies has been carried out to elaborate on an appropriate methodology for personal e-learning environments in primary, secondary and higher education. Working with 3600 students (1st to 12th grades), the Institute conducted various studies to test instructional effectiveness of e-learning tools, including ones related to digital textbooks. For example, in 2010 e-Books were introduced in public education. Within the framework of the programme 7th and 11th grade students received e-Book readers for personal use along with the necessary educational materials in e-Book form. Since these devices could be taken home, the students could use the same ICT device both in and out of school. This research results suggest that the e-Books can be best used with the older age groups in a supplementary, mostly text collection form (Kis-Tóth, Fülep and Racsko 2013). Students in higher grades used the e-Book reader in a much more creative manner, as they developed a Hungarian language keyboard, and searched for and downloaded contents. Younger students used the device for solving targeted tasks given by the teachers and were less tolerant towards the perceived disadvantages of the devices, including the limitations on multimedia functionality and slowness (or even non-existent) Internet connectivity. In the case of both age groups, access to the Internet was essential to effective use.

The next study was conducted in 2011 and focused on enabling teachers to expand their repertoire of resources via the use of tablets and the relevant applications. Due to the respective disadvantages including difficulty in working with multimedia content and declining battery capacity, and the unavoidable amortization caused by excessive use, the previously used Classmate PC and the e-Book readers were exchanged. Students, however, could no longer take their devices home and could only use them in school. In one class, students received e-textbooks produced by the Mozaik Publishing Company in addition to tablets. The textbooks were provided in a static PDF format combining the traditional texts and contents available on new platforms. The research programme aimed to identify the conditions facilitating the effectiveness and efficacy of tablet use in public education. This study suggested that e-Books could be utilized with any age group, however, compared to earlier studies, content and quality were considered of higher importance than the infrastructure tools. Teachers gave complex searching tasks to students and the respective discovery and activity-based learning is reported to have promoted their transversal skills (Kis-Tóth, Fülep and Racsko 2013).

The next phase of the research programme was launched in the first semester of the 2012/2013 academic year during which the static textbooks were superseded by interactive iBook devices. The resources were elaborated by the development team of the Institute of Media Informatics and the participating instructors. The subject matter provided by the texts of the National Textbook Publishing Company was digitally rendered according to the instructions of the respective teachers, and newly developed interactive tests were included as well. For the duration of the study, traditional printed textbooks were not used. While the interactive textbooks contributed to the expansion of learning and teaching options, the platform-dependence on iPad devices limited usability. The other problem was that the devices could not be taken out of the classroom, thus students could not take advantage of the full range of pedagogical opportunities afforded by the devices and resources at home.

In the 2013/2014 academic year a new programme aimed to expand the use of tablets and interactive educational materials as one class from grades 1, 3, 6, 9, was instituted. In grade 9 students used Samsung tablets while other grades studied with iPad2 devices. While first grade students primarily used the instruments for practices and drills, an electronic workbook was prepared for third grade pupils. The eBook titled éRTEm was designed to improve reading comprehension skills including interactive tasks and talking books for listening comprehension practice as well. The subject matter was prepared by Lászlóné Molnár, while the multimedia context was developed by the ICT research group of the Eszterházy Károly University (Antal and Kis-Tóth 2015). A similar workbook was prepared for grade 6 for natural science subjects as well.

Each of the school-based studies emphasized new methods while highlighting the autonomy of the teachers and providing the respective technological and methodological support. The results suggest that successful long-term implementation of digital resources and infrastructure cannot be attained without the encouraging the involvement and creativity of teachers (Herzog and Racsko 2015; Kis-Tóth, Borbás and Kárpáti 2014).

Box 5-5 A case of top-down digital education transformation in China (by Deng Chen and Russell Hazard)

Since the 18th party congress in 2012, the Chinese government has been offering policy support and financial assistance to digitalize traditional industries. The concept of "Internet Plus" was then developed in a government work report in 2015, encouraging traditional industries to use the Internet to better meet peoples' needs (The State Council of the People's Republic of China 2012). The Ministry of Education responded to the national call quickly and released The Ten-Year Development Plan of Education Informatization 2011–2020 (Ministry of Education of the People's Republic of China 2011), aiming to provide broadband connectivity to all K-12 classrooms by 2020 and proposing all provinces start digital education trials by 2015.

Favourable policies and capital support accelerated the development of digital education, including the digitalization of textbook and other traditional learning materials

Propelled by policy support and capital inflows, China's digital education industry has expanded at a rate of around 20% annually in recent years (Research in China 2015). As part of the digital education industry, the digitalization of textbook and other traditional learning resources has been an area that has attracted Chinese authorities, education publishers, internet companies, and other stakeholders.

Chinese authorities have launched several digital textbook initiatives since 2011, one being the e-Schoolbag project. e-Schoolbag is a tool offering a number of online resources including textbooks, notebooks, pens, parents' contact book and other documents which can all be accessed through a digital device just like a "schoolbag" (Zhu 2011). The e-Schoolbag initiative started in 2012 when the Chinese government proposed a new work item on e-Textbooks for the ISO standardization sub-committee working on learning technology standards (ISO/IEC JTC 1/SC 36), generating an international interest in new design ideas behind the e-Schoolbag ecosystem. The role of standards has been emphasized in the project since. The Chinese e-Textbook and e-Schoolbag Standards Working Group was founded soon after. More than 50 education institutions were involved in research and developing standards (Huang 2015). National standards

were later released as requirements for all products. Provincial and local regulations were then drafted to specify and interpret both terminology and standards. Today e-Schoolbag serves as an umbrella concept of large-scale Chinese implementation of digital textbooks and related services and pilot projects have been reported since. However, there seems to be little systematic research either on the design or on the impact of this initiative in the Chinese research literature (Hoel 2015).

As well as governmental initiatives, many traditional state-owned education publishing organizations, with their advantages in terms of large existing content databases and government support, have taken the lead on other major digital education projects. For example, China Education Publishing and Media Group is the biggest educational publisher in China with the market share accounting for 60 %, 25% and 30 % in primary education, higher education, and vocational education, respectively.[116] One group member, People's Education Press, has been directly involved in the curriculum and syllabus design for the nine-year compulsory education system, and has published 11 editions of national textbooks in all subjects; thus far, it has utilized its textbook resources to launch www.Pepedu.net and www.Gopep.cn, two teaching resources websites that cover all subjects for basic education with 2 million subscribed users.[117] Another state-owned publisher, Higher Education Press is the biggest and most authoritative higher education publisher in China. It runs iCourse, the largest MOOC platform in China in terms of both number of courses and number of users, and the "China University Students Online" website (www.univs.cn) with over 2 million registered users from 300 universities and colleges.[118] Other educational institutions and internet companies have also been developing new digital education resources to fill voids in the rapidly evolving digital education market. Of these new digital education resources, one that has shown especially explosive growth is 17zuoye, a K-12 online education platform based in Beijing with over 60 million subscribed users (see **Box 3-3**). Recently 17zuoye also started addressing inclusive education, for example by helping develop online learning in the Jinzhan Hope School, a primary school in a low resource area in China; it also connected physically challenged students in Yuren Learning Center to foreign English teachers abroad through its online courses (17 Edtech Corporation 2019).

A potential challenge due to policy change

In late August 2018, the Ministry of Education together with seven other government departments launched a multilayered action plan to help battle nearsightedness in students in primary and secondary schools. It forbids students from bringing mobile phones and electronic devices to class, and also asks teachers not to rely on electronic devices when teaching and giving assignments (Ministry of Education of the People's Republic of China 2018). Shandong province and Zhejiang province have already issued draft regulations. Considering that the success of 17zuoye has been heavily reliant on favorable government policies, that it is used heavily in schools, that it relies on alignment with the education system/curriculum and the big data from its subscribed teachers and students, it is possible that these changes will adversely impact continued future scaling. 17zuoye is currently developing offline solutions to respond to policies and student needs (Luo 2019).

116 http://www.cepmg.com.cn/
117 http://www.pep.com.cn/rjgl/rjjj/201112/t20111221_1089877.shtml
118 Retrieved from http://www.hep.com.cn/aboutus/intro

Box 5-6 Lycées 4.0 (by Éric Bruillard and Xavier Levoin)

This contribution aims at making visible different components underlying the implementation of a digital textbook distribution operation in a large territory, including the stakeholders and the logistical and financial arrangements involved. The goal is to better articulate material and financial conditions with pedagogical conditions.

From paper to digital textbooks: an incentive during a change in administrative organization

While France is a centralised state, decentralisation laws have led to local authorities' participating in the management of the school system, apart from the educational or pedagogical aspects (prescribed curricula, teachers' salaries, etc.) which remain under the direct control of the State. This system, divided into three distinct segments (primary school, middle school, high school) has been entrusted respectively to the three basic levels of local authorities: municipalities, departments, regions. For the first two levels, textbooks have been provided free of charge to all pupils for a very long time. In the case of the high school (Lycées) (grade 10 to 12), parents had to buy textbooks. Over the past twenty years, various regions have proposed to ensure that textbooks are free for all or some students, sometimes depending on the family's incomes.

In 2015, the French government decided to group the regions into larger regions. The Grand Est (Broad East) region was thus created, resulting from the merger of the former Alsace, Lorraine and Champagne-Ardenne regions. It has a population of nearly 5,600,000 inhabitants over 57,433 km^2. Since the textbook distribution systems in the old regions were different, rather than attempting some kind of harmonization, the new region preferred to replace the purchase of paper textbooks with the purchase of digital textbooks.

This decision extends its action around digital issues in education, since the regions are in charge, for high schools, of technical infrastructure, network operations, broadband access, collective procurement of computers, and assistance and maintenance teams.

For the Region, the Lycées 4.0 initiative is in line with its proactive policy in order to "anticipate the new challenges of the fourth industrial revolution".[119]

For the Rectorate (academic authorities), support teachers' practices, go beyond digital textbooks to facilitate the dissemination and use of digital educational resources

The project was announced in September 2016 and work began with the Rectorate, who studied the best conditions of use for both students and teachers. For students, a strong pedagogical choice was made: to facilitate use both within and outside the school, in non-continuous uses, but on demand under the control of teachers in the classroom and the choice of pupils at home. The decision was made not to install new computer rooms in schools, but instead to have students use mobile personal computers and offer easily usable digital workspaces and easy, secure and fast connections so as not to break the interaction dynamics in the classroom with lengthy activation times.

The Rectorate convinced the Region not to limit itself to digital textbooks but to extend them to digital educational resources: teachers' practices are not limited to using textbooks but combining multiple educational resources. It was deemed necessary both to support current practices and to facilitate the emergence of new practices requiring digital resources.

What is essential to the project is the BYOD (Bring Your Own Device) model. For this to work, the project needs to ensure: (1) mobile computer equipment for students (usable both in the

119 https://www.grandest.fr/srdeii-7-orientations-strategiques/

classroom and at home); (2) Wi-Fi infrastructure in high schools; and (3) the availability of digital textbooks and digital resources.

Purchase subsidy of mobile equipment: the central role of schools

The project was announced in January 2017. Rather than focusing on a few classes, the project was implemented across all classes in the pilot schools. It avoided an intermediate model, in which some of the teachers in a school would use paper textbooks while others would have digital textbooks. A call for tenders was issued to high schools to participate in the operation, and 49 high schools were selected in September 2017 and additional 62 schools in September 2018.

For the high schools selected, the Region provided:

- Financial assistance for the acquisition of individual computer equipment taking into account family incomes;
- Prepaid access to digital resources and textbooks to replace traditional books, because the Region takes charge of all the licences necessary for the use of digital resources and textbooks; and
- secure access from Digital Workspaces.

A website (dedicated to youth https://www.jeunest.fr/lycee-4-0/) makes it possible for students to order the machines and for schools to contact their parents, provide assistance in writing orders and in getting the system up and running.

Respect for teachers' pedagogical freedom: an expandable catalogue from which everyone can draw

Digital textbooks and educational resources can be selected from a catalogue set up by a bookseller that links the offers of school publishers and EdTech companies to the choices of Lycées 4.0 teachers. A teacher may ask to add a resource that is not in the catalogue. A publisher may also request that resources it offers be included in the catalogue. There is no censorship, but a commission is to be provided to the bookseller who manages the catalogue. Experience shows that this system is well suited for digital textbooks, not necessarily to smaller resources (due to the commission charged by the intermediary).

This catalogue gives greater freedom of choice: a teacher can choose different resources from those chosen by colleagues in the same subject and can change the following year, while generally paper textbooks were chosen for four years.

Supporting schools and teachers in the 4.0 dynamic

The Rectorate provides support to institutions for the implementation of this project. The equivalent of one half-time person in each school, called a *4.0 referent*, helps to set up the system. In addition, a group of trainers provides support such as targeted training on demand in the school, sharing of experiences, and suggestions of teaching tools.

To sum up, many actors are involved. A transition from paper to digital textbooks goes beyond thinking solely in terms of digital educational resources and involves setting up a general infrastructure that makes the different choices made by teachers compatible, respecting history and the forms of work installed: the choice of textbooks and resources is left to teachers. Lycées are the local intermediaries between families and the Region and act as a link between parents, teachers and services in order to provide educational facilities and resources.

The lesson is to avoid situations in which new technology is implemented in such a way that it unnecessarily limits teacher choice. For example, in many universities, Moodle is the singular system people are required to use. Other universities have a different platform. Of course there are considerations such as quality assurance and reasonable standardization. However, wherever possible it is important to allow local actors to choose what they feel optimally supports and extends their contextualized pedagogy.

The big challenge is to articulate a dual approach based on both remote platforms and schools providing proximity and assistance:

- A top-down approach (Region), absolutely necessary to design a reliable and secure infrastructure, common tools, and to ensure collective use in good conditions
- A bottom-up approach (Rectorate), to facilitate the evolution of practices, both student and teacher practices, allowing and respecting diverse pedagogical choices

Some figures

Wave 1 (2017): 49 high schools and 32,000 students

Wave 2 (2018): 62 high schools and 35,000 students

Target: all schools of the Region, 355 high schools and 215,000 students for 2021

Cost of pedagogical resources: 56 euros per student (including digital textbooks)

Box 5-7 Germany's Strategy on Education in the Digital World (by Lorenz Denks)

The German Education System consists of 16 sub-systems. Sixteen German States (Bundesländer) administer education in their own zone of responsibility without the intervention of the federal government. The states provide the frameworks on schooling as part of their responsibilities, but they share many similarities because of strategies published on behalf of the federal government[120] but also because of agreements of the States at the KMK (Standing Conference of the Ministers of Education and Cultural Affairs). KMK is the assembly of the education ministers of the German states and develops common standards to ensure alignment across the school systems in different states.

The KMK presented in December 2016 a strategy "Education in the Digital World"[121] outlining what formal education in times of digitalization has to deliver and proposing actions which should be taken in terms of:

a. Education plans and curriculum development;
b. Initial, further and continuing education of educators and teachers;
c. Infrastructure and equipment;
d. Educational media;

120 See, for example, WBGU -Wissenschaftliche Beirat der Bundesregierung Globale Umweltveränderungen: Digitalisierung: Worüber wir jetzt reden müssen, available at https://www.wbgu.de/de/publikationen/publikation/digitalisierung-worueber-wir-jetzt-reden-muessen; BMBF (Ed.) : Bildungsoffensive für die digitale Wissensgesellschaft. Strategie des Bundesministeriums für Bildung und Forschung, available at www.bmbf.de/pub/Bildungsoffensive_fuer_die_digitale_Wissensgesellschaft.pdf

121 Sekretariat der Kultusministerkonferenz: Bildung in der digitalen Welt Strategie der Kultusministerkonferenz, available at https://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2018/Strategie_Bildung_in_der_digitalen_Welt_idF._vom_07.12.2017.pdf ; English summary available at https://www.kmk.org/fileadmin/Dateien/pdf/PresseUndAktuelles/2017/KMK-Strategie_Bildung_in_der_digitalen_Welt_Zusammenfassung_en.pdf <18.070.2019>

e. E-government and school administration programmes, education and campus management systems; and

f. Legal and functional framework.

The strategy notes different aspects of digital education media. On a positive note, the development of content opens up in a way that allows students, teachers or any interested person or institution to become a content producer and share the products. By using open license models (e.g. Creative Commons) the composition, publishing and distribution process for media is relatively simple and flexible. Digital education media also give new options in terms of direct feedback and direct communications, open up new ways of offering individualized media for different leaning channels and different approaches, and give a wide range of options for student participation.

The strategy paper identifies three main areas in which the states are recommended to find common solutions (pp.31-36):

1. **Quality:** The fact that content creation becomes easier through digital media also means that there is a need to ensure quality in the offered materials. Therefore, the German states should implement new ways of quality management, e.g. by approval systems, quality criteria or offering catalogues listing high quality media.
2. **Technical Issues:** To ensure an easy and wide usage, educational media should be offered on all main operating systems and different types of devices. Therefore, technical standards need to be implemented as well as concepts for hybrid usage of digital and non-digital media. In the process of developing infrastructure for the usage of digital education media it is critical to align it with the data protection laws, in order to protect the personal data of students and teachers, as well as with youth protection and copyright laws.
3. **Legal challenges:** Data protection, youth protection and copyright are the core challenges in the area of legal challenges. The strategy suggests that copyright should be modified in order to support new forms of learning but also include the interests of media producers and editing companies.

Although the decisions of the KMK are non-binding and the implementation of the strategy depends on the political environments in the individual states, the discussion on digitalization picked up speed within the last years. This led to an initiative called "Digitalpakt Schule", in which the federal government offers 5 Billion Euro for the development of digital infrastructure in schools (applied for by the communal school administrations) while the states are responsible for the pedagogical frameworks (based on the KMK Strategy) and content starting in 2019.

Different studies (see, for example, Schmid, Goertz and Behrens 2017) suggest that the usage of digital technologies overall in German schools is still not the new normal and that skilled teachers and good hardware are more exceptions than the norm. The situation is very different, depending on the individual school. Schools in Germany decide on their own school concept, school curriculum (as long as it is in line with the state curriculum), and textbooks and materials, while the overarching infrastructure is provided on the communal level. This explains vast differences across schools in terms of digitalization. While some schools deliver their lessons almost completely digitally, working with a variety of apps and learning environments, other schools hardly have internet access. It depends on factors at all levels: the school and its staff, the school administration on the local level and the state. The interest in digitization, funding, and priorities of the key actors determine the outcomes of schools in terms of digitalization in Germany.

Box 5-8 Digital teaching and learning in the United States: How a decentralized, multi-Tiered education system supports effective use of technology (by Boyka Parfitt and Ji Soo Song, ISTE)

Due to the decentralized, multi-tiered nature of the American education system, federal, state, and local governments all play a unique and significant role in enacting policies for EdTech implementation. While the federal government is able to influence the national vision for what education transformed through EdTech looks like and provide some financial supports, state and local governments ultimately determine the 'what' and 'how' of teaching and learning and provide a majority of education funding. Below, we describe some of the policy levers used by federal, state, and local governments to incorporate edtech in American classrooms.

Federal level policies

Articulating a shared vision through a national edtech plan

The Office of Educational Technology (OET) is mandated by the U.S. Congress to publish a "national long-range technology plan," which outlines how technology may be most effectively used to promote teaching and learning (U.S. Department of Education n.d.). In January 2017, OET published the latest iteration of the National Education Technology Plan, titled "Reimagining the Role of Technology in Education." This policy document articulates a shared vision of "equity, active use, and collaborative leadership to make everywhere, all-the-time learning possible" and aims to guide the efforts of various stakeholders, including teachers, policymakers, administrators, and teacher preparation professionals (OET 2017). The plan provides actionable recommendations for these stakeholders, as well as real-life examples of successful implementation strategies led by states and districts.

Providing funds designed to support implementation

While setting a vision that recognizes the power of technology to transform education is an important milestone, making sound investments into programs that support the implementation of this vision is essential for producing improvements at scale. Title IV, Part A of the Every Student Succeeds Act (ESSA) authorizes the Student Support and Academic Enrichment (SSAE) grant program. This block grant provides funds to support three broad categories of programs and activities: well-rounded education, safe and healthy schools, and the effective use of technology. This federal investment allows states and districts to flexibly implement a number of programs and activities that can support the national vision of education transformation through technology (Bernstein et al. 2019).

Supporting the use of open educational resources

In 2016, OET launched the #GoOpen Campaign to increase educators' awareness of Open educational resources (OER), catalyze communities of practice, encourage infrastructure investments, and identify sustainable models for OER implementation. Specific efforts under this initiative included publishing a story engine that highlights districts successfully using OER, developing strategic partnerships with educational nonprofits and private-sector companies, and coordinating collaborative opportunities through national and regional summits. Since then, over 100 districts have committed to replace at least one proprietary textbook with OER. Twenty #GoOpen states have also committed to support districts' OER option processes (ISTE 2018a).

State level policies

State policymakers — including governors, legislatures, boards of education, and education agencies — each play a critical role in establishing and implementing the state's laws and

regulations, specifically to ensure the maximum impact of previous investments in broadband and classroom technology. Identified below are three core policies that state governments can pursue to support such efforts.

State education agencies serve as a bridge between educators and policymakers, and thus can convene a diverse group of state leaders, edtech experts, and district stakeholders — such as students, teachers and parents — to establish a framework for digital teaching and learning. Connecticut (Connecticut Commission for Educational Technology 2016; Connecticut Department of Education 2018) and Vermont (Drescher 2017) are currently among 13 states that have adopted, adapted or endorsed the newest iteration of the International Society for Technology in Education's (ISTE) Standards. In addition to the Student Standards, ISTE developed the ISTE Standards for Educators and the ISTE Certification program to build educators' capacity to use technology in the classroom. Utah incentivizes educators to build their proficiency in the effective use of edtech by providing a state endorsement tied to salary increases (Utah Education Network, n.d.). The state permits educators to meet the requirements for this endorsement by earning an ISTE Certification.

Furthermore, the Utah State Board of Education established a Digital Teaching and Learning Grant ($10 million in 2016; $20 million in 2018), providing a successful example of advocating for and securing budgets that support edtech priorities (Utah State Board of Education, n.d.). Among other uses, grant dollars can be used by districts to fund teacher participation in the state's Education Technology Endorsement Program (Utah Education Network n.d.).

Local level policies

Of the three tiers of the American education system, local policymakers, such as the district school board and local educational agency, have the most direct contact with educators and students. Therefore, local policymakers have an opportunity to deliberately craft policies that specifically meet the unique needs and challenges of their stakeholders.

The Los Angeles Unified School District (LAUSD), the largest public school district in the United States, faced a significant challenge when district leaders, after purchasing a large number of devices through the Common Core Technology Project, realized that their educators did not have the knowledge necessary to use the devices to promote students' engagement in active learning opportunities. District leaders formed a task force to lead efforts that would reinforce LAUSD educators' capacities to effectively use technology, using the ISTE standards (Snelling 2018).

For example, one approach that LAUSD leaders took to apply the ISTE Standards was by introducing digital citizenship — students' recognition of the rights, responsibilities and opportunities of living, learning and working in an interconnected digital world, as they act and model in ways that are safe, legal and ethical — into classrooms.

Assessing the key areas where investments would be most impactful is an important task for state and local decision makers. ISTE's *Using ESSA to Fund Edtech* is a policy implementation guide that provides recommendations and examples of ways digital tools can be used to enhance a diverse array of educational initiatives such as STEM, social and emotional learning, college and career counseling, positive behavior interventions and supports, violence prevention, and conflict resolution (ISTE 2018b). For example, school districts in Georgia have used Title IV-A funds to support student-led STEM clubs (Harris 2018).

Note: Boyka Parfitt is manager of Government and External Relations at ISTE and Ji Soo Song is Policy and Advocacy Associate at ISTE.

Box 5-9 Digital silk highway: Infrastructural challenges for e-learning in Central Asia

E-learning as educational priority in Central Asia

A number of government initiatives to promote e-learning has been observed in Central Asian countries in recent years. In 2011, **Kazakhstan** launched the project "E-Learning System". Education policy in Kazakhstan has put the development of domestic digital education resources as one of its eight strategic goals in the area of informatisation of education, along with addressing hardware and infrastructural needs.

In June 2017, the Government of the **Kyrgyz Republic** publicly announced that it would be designing new digital transformation program titled *Taza Koom*, which would comprise one of the main pillars of the National Sustainable Development Strategy for 2040. The Kyrgyz Ministry of Education and Science started testing new IT curriculum in secondary schools in 2016-2017.

In 2015 the Government of **Tajikistan** decided to discontinue existing correspondence-based programmes for part-time students and shift to a "distance learning" system which utilizes the Internet. Tajikistan is moving towards the use of existing courses from different online platforms such as Coursera, Codecademy, Lingualeo and Intuit.ru. for teacher training, life-long learning and supplementary learning materials. Other digitalization of education measures include knowledge exchanges with open universities in Malaysia, Indonesia, South Africa and the United States and the use of learning management systems.

The **Turkmenistan** government is also keen on digitalising the educational system. In 2017, President Gurbanguly Berdymuhamedov approved the concept of digital educational system development and the plan for its implementation, which envisages the establishment of a Center for Innovative Information. The Center will be coordinated by the Ministry of Education, which will be responsible for developing e-learning methods, including digital textbooks, video and audio materials, interactive and multimedia programmes.

Internet at the heart of e-learning initiatives: a common regional network

Across much of Central Asia, however, the Internet is considered to be a hindering factor to fully realize the potential of e-learning. For example, according to 2017 Digital Development Assessment study supported by the World Bank Global Smart Nations programme, Kyrgyz Republic is "heavily dependent on neighbouring Kazakhstan for internet-traffic transit and pays significantly higher prices for international bandwidth than more developed markets. Connections to Tajikistan and Uzbekistan also exist but are not fully utilized to accommodate bandwidth demand, in part because of the high cost of bandwidth in those countries compared to transit purchased via Kazakhstan. Internet-service providers (ISP) in Kyrgyzstan also intend to increase link to China in order to improve redundancy of international connectivity" (p.41).[122]Co-founded by the European Union (EU) and launched in 2010, the Central Asian Research and Education Network (CAREN)[123] sets out to create a high-capacity data-communications network for researchers, academics and students at over 300 institutions in Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan. CAREN is an EU-funded project, initiated in 2009 and currently in its third phase (2015-2019), which provides high-speed broadband connectivity for not-for-profit use. The CAREN connects the national research and education networks (NRENs) of four Central Asian countries—Kazakhstan (KazRENA), Kyrgyrstan (KRENA), Tajikistan (TARENA) and Turkmenistan (TURENA). In addition to facilitating communication, information exchange and collaboration between academic

122 http://www.ict.gov.kg/uploads/ckfinder/files/KG_Digital%20Development%20Assessment_Final.pdf
123 https://caren.geant.org/Pages/Home.aspx

and research institutions within the region, CAREN aims at providing access to the European and global research community through counterpart networks in Europe (GÉANT), Asia-Pacific (TEIN) and Eastern Partnership countries (EaPConnect).

CAREN is preceded by the "Virtual Silk Highway" project, which was sponsored by the North Atlantic Treaty Organization (NATO)—an intergovernmental military alliance. Following the collapse of the Soviet Union, scientific communities in the newly independent states in the Southern Caucasus (Armenia, Azerbaijan and Georgia) and Central Asia (Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan) saw their budgets dramatically reduced. In response to this challenge, in 1994, the NATO's Science Programme launched the Virtual Silk Highway Project to promote local networking among academic and scientific institutions by building a satellite-based network for these eight countries. According to the NATO review in 2002,[124] the Virtual Silk Highway project was then "the largest and most ambitious project to have been sponsored by the NATO Science Programme" in its 44-year history.

What's in the name: Great Silk Road to Digital Silk Highway

> *For centuries the Silk Road was the long-distance route for trade and communication across Central Asia. Today, CAREN is upgrading this route to a 21st century high-speed Internet highway for research and education institutions throughout the region.*
>
> Central Asian Research and Education Network (CAREN) website[125]

Over 20 years of effort to support the infrastructural development in Central Asia are revealing in terms of understanding some of the challenges of digitalization of education. The first challenge is rapid technological advancement and the need for infrastructural renewals. CAREN aims to improve intra-regional connectivity across Central Asia by replacing existing "low-capacity" satellite connections with terrestrial fibre. This means that what was the "state-of-the art" satellite technology under the Virtual Silk Highway project has become something to be replaced under the CAREN project in less than a decade.

The second challenge is a complex one which is linked to the (hidden and manifest) agenda of the donors reflected in the association of the project with the Silk Road. In a sense, it is not surprising that the Virtual Silk Project and CAREN were sponsored by actors interested in detaching Central Asian states from the Soviet past and quarantining them against the spread of anti-Western Islamic extremism (see Niyozov and Dastambuev 2012 for strategies of international donors in Central Asia). Surveying the evolution of the Internet from a military experiment in the context of the Cold War to a "General Purpose Technology" today, Naughton (2016) has shown that the Internet has been shaped, not simply by its underpinning technologies, but also by political, ideological, social, and economic factors. In the newly independent Central Asian countries, forces shaping the development of the network have been much more visible than in countries that did not experience social and political ruptures.

In a brochure introducing the Virtual Silk Project, NATO wrote: "In addition to promoting the international cooperation essential to the progress of science, the Science Programme also serves to promote peace by fostering trust and understanding and by forging enduring links between scientists throughout the Euro-Atlantic region."[126] This suggests that the Virtual Silk Highway project was not simply about ensuring connectivity among educational and research institutions

124 https://www.nato.int/docu/review/2002/Examining-Enlargment/silk-highway/EN/index.htm
125 https://caren.geant.org/Pages/Home.aspx
126 https://www.nato.int/docu/virtual_silk_highway/virtual_silk_highway.pdf

in Central Asia but also about forging alliance with Central Asian scientists who had been trained in the Soviet system. This speaks to the challenge of maintaining cultural, intellectual and political autonomy of a national communications network in a digital age—especially when the infrastructural development is supported by international donors.

Box 5-10 The SolarSPELL offline digital library (by Kristen Linzy and Laura Hosman)

SolarSPELL (Solar Powered Educational Learning Library) is a solar powered, easy to use, offline digital library, designed to simulate an online experience. SolarSPELL libraries generate an offline Wi-Fi hotspot, to which any Wi-Fi capable device (smartphones, tablets, or laptops) can connect, allowing individuals to surf the library's resources for free. This innovative design eliminates the need for Internet connectivity or reliable electricity, while increasing access to quality educational content in resource-constrained locations. Each library version is tailored to the region, ensuring the materials are informative and engaging for local communities. Open-access resources are available across seven content categories, including: Creative Arts, Environment, Health and Safety, Language Arts, Math, Science, and Local Topics. SolarSPELL digital libraries provide a platform for novice technology users to develop increased digital literacy while navigating an Internet-like interface.

SolarSPELL in the Pacific Islands

To date, SolarSPELL has deployed over 200 digital libraries across Vanuatu, Samoa, Fiji, Tonga, and the Federated States of Micronesia. The remote nature of the Pacific Islands, combined with the unique infrastructural and environmental challenges that Pacific Islanders face, necessitated an innovative solution to providing library access. For communities with limited exposure to libraries, it is crucial to provide on-site training when introducing SolarSPELL digital libraries. During training, facilitators become comfortable connecting to the offline server and navigating the library catalogue, while engaging in interactive activities to brainstorm approaches for integrating the resources into the classroom. The trained facilitators are then poised to continue training additional members of the community, in a train-the-trainer model, creating a sustainable implementation model. In the Pacific Islands, SolarSPELL has collaborated with U.S. Peace Corps Volunteers for four years. The following study evaluates the impact of SolarSPELL digital libraries in Vanuatu.

Methodology

This study was conducted in December of 2017, across two islands of Vanuatu: Efate and Malekula. The data informing this study was obtained through in-person interviews. Participants were selected using purposive sampling; the study's participants were all education or health care Peace Corps Volunteers (PCVs), who had received formal SolarSPELL training and received a digital library. Since the Peace Corps Volunteers were technology and Internet savvy, they were asked to report on both their own use of SolarSPELL, and their observations of SolarSPELL use by the local community. Interview questions covered: demographics (population served, site location), resources (accessibility of Internet and electricity), SolarSPELL content and implementation (how SolarSPELLs were being used), technology (prevalence and perception of technology), and job satisfaction (measuring potential impact of SolarSPELL on the PCV's efficacy in their role). Audio recordings were collected, transcribed into written documents following completion of the study, and analyzed to identify key themes.

Results

Anecdotal evidence informed the following key areas for data analysis: improved access to both the quantity and quality of educational resources, the importance of having a reliable offline source of information, and fostering the initial stages of developing information literacy.

Improved access to the quantity and quality of Resources

Peace Corps Volunteers consistently reported one of the greatest outcomes of having a SolarSPELL was the unprecedented access to information offered on the digital library. When asked about the frequency of use, one participant reported: *"The teachers use it all the time,"* explaining, *"A lot of what they have in their textbooks is quite limited."*

In addition to providing content on a broad range of topics, the SolarSPELL has also provided local teachers with new options for supplementing their lessons. A second participant shared the greatest outcome was *"teachers realizing that there are resources for them out there in the world..."* Similarly, a third PCV reported the greatest outcome was *"providing resources to a teacher who otherwise might not have had access to them, or who is maybe not regularly going to browse our [unreliable] Internet connection for teaching resources, nor know the websites to go to."*

Importance of self-sustaining, offline educational resources

SolarSPELL was founded to address frequent barriers to accessing quality educational content, particularly barriers caused by intermittent or cost-prohibitive access to the Internet and electricity. This reality was conveyed through several of the interviews in this study. One PCV succinctly summarized this challenge, stating *"even though I do have Internet, [SolarSPELL] is still really helpful because Internet service is not reliable."*

In other instances, volunteers reported frequent barriers to using technologies that require a source of electricity. For example, when asked about the community's perception of technology, one volunteer explained: *"We really want technology, but the power situation is hard right now, everything just feels expensive."* In the event that the power source stops functioning, the remote nature of these villages presents additional complications to fixing the issue. One participant shared how when their generator breaks, they are required to *"carry it over a really big hill and down into the village"* for repairs. The portable, solar-powered, offline design of SolarSPELL assists in reducing these limitations and increases reliable access to the library's content.

Developing information literacy

For communities whose resource-constraints have previously limited the scope of information available to them, developing information literacy skills is crucial once their access has been expanded. A key theme that emerged throughout the interviews was the potential for SolarSPELL to teach users how to search for content to address their questions. When asked about the best outcome of having a SolarSPELL, one Peace Corps Volunteer immediately responded, *"I think the best outcome is being able to familiarize students with how to find what they're looking for,"* which the Peace Corps Volunteer felt *"has been fueling the kids' curiosity."*

Furthermore, SolarSPELL libraries offer a safe platform for learners to engage with content on a broad range of topics, and notably, content that has been vetted and verified as a reliable resource. As SolarSPELL users become comfortable navigating the library to search for content, it provides *"a good way to ease into the World Wide Web because it's a soft way to practice the skills to use*

technology to find out what you want to find" without immediately introducing the challenges that accompany having access to all of the Internet's sources — reputable or otherwise.

Discussion and concluding remarks

Although this study focuses on the use of SolarSPELL digital libraries in Vanuatu, the findings that emerged offer broader implications for the role of digital libraries in addressing the educational needs of resource-constrained regions. Most notably, the need for an innovative technological solution that can offer all of the resources of a traditional library, through a self-powered, offline platform. Additionally, this study highlighted the importance of implementing digital libraries with an on-site collaborator, who can continue to facilitate the development of information and digital literacy skills in novice digital library users. With these factors in place, the digital libraries were able to overcome pervasive challenges faced when seeking (or providing) access to quality educational content in low-resource settings. Leveraging open access resources, and pioneering the design of a simplified technology, extends the power that libraries hold for transforming people's lives, to previously unconnected populations. Addressing this paramount need has limitless implications for improving individuals' quality of life and for empowering the populations who are most at-risk for experiencing an educational divide.

Box 5-11 Populating national learning platforms with OERs: Cases of Kenya and Uganda (by Ariam Mogos)

Examples of government initiatives from Kenya and Uganda provide a brief overview of how national governments in Africa are trying to populate national learning platforms with OERs and challenges they are facing in finding local digital content.

Digital Literacy Programme in Kenya

In 2013, the Kenyan government under the directive of President Uhuru Kenyatta launched the Digital Literacy Programme (DLP), a bold initiative to ensure every Kenyan child is digitally literate for the 21st century. The primary goals of the DLP are to equip all public schools with robust ICT infrastructure to support digital learning programming (with a focus on equity and access), facilitate the acquisition of quality digital content that will enhance digital literacy and other 21st century skills, and develop the capacity of education professionals to use ICTs in the learning and teaching processes. The key components to execute these goals have been the distribution of digital devices for students, last mile connectivity, the acquisition of digital content, quality assurance of digital content and teacher training. To date, 1.2 million digischool devices (laptops) have been distributed to students in class one preloaded with content approved by the Kenya Institute of Curriculum Development (KICD) and aligned to Kenya's previous curriculum.[127]

The rollout of Kenya's new competency-based curriculum in 2019 has prioritized the acquisition and alignment of new high-quality digital content for the Kenya Education Cloud,[128] a learning management system developed by the KICD to deliver the DLP. Despite the urgency and emphasis placed on digital interactive content, this has been a significant void within the ecosystem of the DLP that has been difficult to address. It is one of the key factors that has contributed to the low usage rate of DLP devices by teachers since 2016. The traditional textbook publishing industry in Kenya has struggled to shift to a digital publishing model, which has hindered the development of digital content. There has been wide speculation that the challenges range from a lack of

127 http://icta.go.ke/digischool/about-digischool/
128 https://kicd.ac.ke/resources/kenya-education-cloud/

technical know-how to concern about unsustainable business models and loss of profits, echoing global concerns from traditional publishers. Alternatively, with support from UNICEF Kenya, the Kenyan government has opted to populate the Kenya Education Cloud with OER, both local and global. While there are many affordances of OER, the most significant being the various creative commons licenses, there is a dearth of OER available for primary learners in Kiswahili, the national language of Kenya, not to mention indigenous languages of Kenya such as Kikuyu and Luo.

To populate the Kenya Education Cloud with high-quality open content, KICD has taken a two-pronged approach which includes (1) identifying and approaching popular local digital content producers willing to provide a subset of content as OER and (2) global digital content producers with open content that meet enough of the competency-based curriculum standards and can be localized for the Kenyan context. Several questions and challenges have been posed throughout this exercise. How will the localization of global OER which requires continuous adaptation be sustained? How will digital content for learning areas such as indigenous languages and Kenyan sign language be produced when they are perceived by content publishers to be "less profitable" because they have a smaller market? As Kenya continues to design and test this process, it produces learnings that other countries on the continent can reflect on and build upon.

Kolibri platform in Uganda

Similar challenges, as well as different kinds of challenges, are seen in the case of Uganda. In 2016, the Ugandan government (Ministry of Education and Sports) in partnership with Maendeleo Foundation, Women in Technology Uganda, and UNICEF Uganda began user testing Kolibri, a digital learning platform populated with OER from Khan Academy, CK-12, Phet and other global content providers. This project falls under *Transforming Computer Labs into Learning Labs*, a larger government initiative which aims to provide adolescents in emergency settings and marginalized contexts (girls in particular) with access to free offline digital learning resources. Kolibri, the primary platform used to deliver these resources is developed by San Diego-based non-profit Learning Equality.[129] Kolibri spun out of KA-lite, a lightweight platform designed to support Khan Academy videos offline.

In 2017, Kolibri was piloted in 30 government-assisted secondary schools with computer labs in ten districts across the country, and 12 youth centers with digital kiosks. Rather than investing in procuring technology, the Ugandan government chose to use existing infrastructure in schools and community centers. This approach has posed an additional set of commonplace challenges with technology which include lack of functioning hardware and outdated operating systems. There have been constraints to designing low-cost maintenance models to address these technology issues. Many schools do not have the resources, technical expertise or staff time to maintain equipment on a routine basis. Moreover, schools with resource shortages reserve electrical power for ICT courses, administrative tasks and power shortages, which limits the use of the existing infrastructure to a subset of the school or community population.

As with Kenya, the demand for local content has been high, and sourcing local OER to meet that demand has been a challenge. The scarcity of local digital content has also contributed to increased scrutiny of content in the vetting and approval process, as there is a general perception that content on digital devices can be negative or not aligned with Ugandan values.

In 2019, the Uganda government received further support for Kolibri implementation through the Global Business Coalitions' REACT initiative, a digital platform for matching business with

129 https://learningequality.org/kolibri/

implementation partners to deliver learning opportunities to children and adolescents affected by crises.[130] The partnership includes UNICEF, UNHCR, HP, Learning Equality and Education Cannot Wait (ECW), and a few of the gaps identified between 2016 and 2018 are actively being addressed by new partners.[131] HP is donating technology and other resources to enlarge the existing repository of devices. To address power issues, the partnership is strengthening solar powered systems, and creating solar powered set-ups at schools. As the roll-out continues in 2019, the identification and sustainable production of local content remains to be one of the highest priority items.

In terms of the Instrument–Actors–Systems triptych, it is first and foremost the instruments themselves, their design and their uses, that are at the heart of this global review of digital textbooks and digital educational media and resources. To complement this focus on the instrument, Chapter 5 has turned attention to policy. This chapter is devoted to issues associated with implementation of digital technologies and resources in different educational contexts. The Instrument–Actors–Systems framework has made it possible to articulate a contrasting series of ten case studies. The last eight of them (**Box 5-4** to **Box 5-11**) in the Systems section describe how different education systems implement policies for the deployment of digital infrastructures and tools in their country or region: in Europe (Hungary, Germany and France), in North America (U.S.), in Asia (China and Central Asia), in Africa (Kenya and Uganda) and in the Pacific (Pacific Islands).

As we are interested in policy, these case studies are primarily at a macro level. We have only two examples of meso-level studies (school-wide), namely, school-based research studies on the use of digital education tools in Hungary and the school-level studies on the SolarSPELL in the Pacific Islands study. Similarly, we report few elements at the micro level, that of the teacher and the class, with the exception of the study of the use of Mincecraft, in the Instrument section.

The very fact that we can report case studies from different continents, with much contrasted examples, indicates that many education systems have taken into account the development of digital technology and have considered policies for its deployment in education. This chapter has presented several initiatives to identify the problems posed by such deployment and how the issue of digital educational resources could be addressed in various contexts.

The next chapter provides some recommendations from the analysis and synthesis work presented in previous chapters. The practical recommendations in the literature most often concern the meso level, since the school is the organizing framework for teaching. It is therefore not a focus of the next chapter. Instead we have recommendations on instruments (textbooks), actors (teachers) and pedagogy (as a system at a micro level).

130 https://gbc-education.org/react-in-action-hp-and-education-cannot-wait-pilot-edtech-program-for-refugee-children-in-uganda/
131 http://www.educationcannotwait.org/connecting-people-with-technology/

CHAPTER 6

Recommendations for Decision Makers

In the preceding chapters of this review, we examined the evolution of digital technologies and some of the questions raised around their use in education. The first chapter introduced these questions by trying to adopt a balanced view between the different positions. The second chapter developed a historical perspective, articulating elements of the history of books and textbooks and recent developments around computers. The third chapter presented a set of digital resources and repositories and platforms of resources, trying to show how the current situation allows us to think differently about the notion of textbooks and their links with digital educational media. This has shed light on a diverse set of resources (see Appendix I), highlighting the opportunities available to educators and learners. The fourth chapter focused on pedagogies and educational situations in which digital resources can provide productive learning opportunities. We proposed a model, structured around eight affordances, to characterize the pedagogical potential of digital educational resources. The fifth chapter was devoted to examining real-word implementation of digital education initiatives in a variety of contexts and from different perspectives. Rather than focusing on the digital education resources themselves, it highlighted actors who intervene in the educational scene as well as educational systems which facilitate, constrain and regulate what can be done in classroom. A set of examples of implementation of digital textbooks and associated initiatives from across the world provided hints and lessons for effective uses of digital technology.

In this chapter, we will propose some recommendations from reviews we have conducted. They are intended for decision makers, which we understand in the sense of all people who make decisions about education ranging from the national level, often policy makers, to the local level of teachers, who have to make many decisions in their daily work, especially in the management of their classrooms. Before presenting the recommendations, we put forward some key considerations in formulating these recommendations and key questions emerging from the preceding chapters.

1. Revisiting Calls for a Shift from 'Education' to 'Learning'

As we have touched upon in different chapters, it has become customary in some circles to embrace an inevitable shift from anachronistic, 'traditional' pedagogies to innovative, 'digital' pedagogies. This is often accompanied by calls for a shift from 'education' to 'learning', with increasing emphasis on competencies, learning outcomes, and learning metrics in all domains of education, including education for peace, sustainable development and global citizenship now enshrined in SDG Target 4.7. What is increasingly discounted together with so-called 'traditional' approaches to education is "foundational principles that have guided international and national education policy and practice" (UNESCO 2015a, p.80). As the excerpts from the *Rethinking Education* report below articulate, we need to be cognizant of tensions between education as understood as "a collective social endeavour" and learning as understood as "an individual process of skill acquisition".

> *It is important to underline that current international education discourse carries with it a potential for undermining foundational principles that have guided international and national education policy and practice. Indeed, the current international education discourse couched in terms of learning is essentially centred on the results of educational processes and tends to neglect the process of learning. In focusing on results, it is essentially referring to learning achievement: that is, to the knowledge and skills that can most easily be measured. It tends thereby to neglect a much wider spectrum of results of learning, involving knowledge, skills, values and attitudes that can be considered important for individual and societal development, on the grounds that they cannot be measured (easily). Furthermore, learning is seen as an individual process of skill acquisition, and little attention is paid to questions of the purpose of education and the organization of learning opportunities as a collective social endeavour. This discourse thus potentially undermines the principle of education as a common good.* (UNESCO 2015a, pp. 80-81)

While we tend to equate 'traditional' education with the knowledge acquisition metaphor and individual memory, it is important to recognize that the emphasis on 'learning' — especially some forms of 'personalized learning' — is equally or even more firmly couched in the acquisition metaphor. We need to be careful not to embrace whatever is digital as necessarily innovative and progressive. Digital media can reproduce, reinforce and even exacerbate forms of transmission pedagogy long in need of reform. In order to harness the pedagogical possibilities opened up by digital technology, it is important to pay attention to the visions of learning underpinning what is touted as digital learning solutions at scale. Rather than privileging one vision over another, we uphold an open and humanistic vision of education that is not limited to a competition in which learning is an internal, individualistic activity. Such vision acknowledges education as a collective experience that offers all students the opportunity to develop their potential to the fullest and to learn to live together on the planet under pressure.

2. Key Questions

Transitioning to digital media in education requires a number of issues to be considered. For example, the literature review conducted in Florida, based on the experiences of school districts that have adopted digital initiatives, included a summary of issues that require attention:

> *Before implementing a digital textbook program, experts recommend that districts select high-quality digital content, address licensing and copyright issues, decide if the district will provide electronic devices to all students or implement a Bring Your Own Device model, determine schools' infrastructure needs, ensure that all students have equitable access to digital textbooks and home Internet connectivity, and provide teachers with professional development.* (Blazer 2013)

A basic digital foundation requires combining (1) infrastructure and equipment (managed at the national or sub-national level), (2) the provision of educational resources, and (3) teacher capacity development. As we have seen, the use of digital educational resources requires the establishment of a sufficient technical infrastructure to allow access under good conditions. Depending on the possibilities, it is necessary to study the best compromises between online and offline and to allow local configuration. CLIx (**Box 4-6**) and SolarSPELL (**Box 5-10**) have offered examples of compromised solutions in the low-resource contexts.

An analogy can be made with the distribution of running water. A good way to look at it is to bring water and let people choose to take baths or showers and install what is needed to ensure local distribution. To provide safe drinking water, additional services must be added and regular monitoring must be carried out. As regards the Internet and digital services, it should be possible to secure access and leave sufficient scope for local actors to take the initiative.

It is critical to provide an enabling work environment and effective accessibility to digital educational resources for students and teachers. The issue of teachers is also central. We have not oriented this review towards replacing teachers with machines; the few promises in this area remain rather unconvincing. We have focused on the ongoing changes in the role and activities of teachers; how they will work with digital educational resources, which they select, create or transform. At the heart of teachers' work is to ensure learner engagement and outcomes, which raises the question of pedagogies they will be able to implement with these resources.

We propose three sets of recommendations directly related to the developments in the previous chapters: the first one on products (Chapter 3), the second on educational situations and pedagogies (Chapter 4), and the third on actors and systems (Chapter 5).

The analysis carried out leads to reflections on three major questions. The first set of questions concerns the technologies themselves—how they are designed and what characteristics they must adopt. Digital textbooks and digital education media are at the heart of this study. How can we think the design of digital textbooks as well as their articulation with other digital resources?

The second set of questions relates to the activities carried out with digital technologies. What opportunities are available to implement the pedagogical forms recommended for a long time, particularly by supporters of new education? In addition, how can they contribute to the quality education agenda?

Finally, the last set of questions concerns teachers and the ongoing transformations. How can the diffusion of digital technologies and social changes lead to changes in the role and identity of teachers? How can teachers be empowered to influence the creation of digital resources and infrastructure decisions in a meaningful, yet realistic way?

3. Key Recommendations

Recommendation 1 concerns products and instruments. Textbooks have largely been a macro-level product and this has posed a problem in use in the classroom, requiring adaptation to local contexts. Here, we argue that digital technology can contribute to reversing the situation, with the textbook designed at local level (micro or meso level) contributing to a macro level offer. Recommendation 2 concerns pedagogy, which can be seen as a system at micro level. Recommendation 3 concerns actors. Teachers' collectives can be broadly at three levels: classroom level, school level, and regional (sub-national), national, or international level.

Recommendation 1: Develop digital textbooks and digital education media that meet the needs of educators and learners

Decision makers need to address:

- The contemporary view of education to give place to many different voices and the emphasis on respecting cultural diversity and the role of culture in sustainable development (as articulated in SDG 4.7)
- Changes in the context, from scarcity (the textbook was the main and sometimes the only resource) to abundance (a wide range of resources available from television, Internet, games and so on)
- The need to support a wide range of individual and collective activities
- The overuse of digital technology by students and difficulties in keeping attention
- Diversity in the mode of production (digital to paper, including OER and local resources)

The main role of digital (and partly printed) textbooks is

- To structure the main content (and summarize the main concepts and topics involved)
- To act as a knowledge organizer, stable and open to external resources
- To act as the locus of student activity, linking to other interactive education resources
- To act as a locally lively resource (possibly in the form of OER and open textbook), mixing different content media and student workspace (traditionally notebooks), with personalisation (and sometimes printing) locally processed.

Recommendations

- Provide accessible and easily readable digital resources by students (and parents).
- Ensure selection of resources in a variety of media, keeping the process of selection transparent and flexible.

- Facilitate the inclusion of new resources (from teachers, students, and others) to meet appropriate student and subject needs.
- Ensure an enabling environment in schools: providing appropriate support to the management of educational resources (licensing and copyright issues; devices; infrastructure; access to the Internet).

Recommendation 2: Optimize the affordances of digital education media and resources for learner engagement and outcomes

Decision makers need to respond to the following concerns:

- There is an emerging general consensus around new aims for education to enable young people to engage creatively and responsibly with the world. There is a need to shift from a culture of competition and reinforcing instrumentalist vision of education to a culture of collaboration and embracing holistic vision of education.
- The affordances of the digital have not been sufficiently harnessed to support learner-centred pedagogy for these goals. This development process needs to be strategic, as digital affordances should serve well-conceived pedagogy.
- In terms of the provision of educational resources, we have discussed the importance of OERs and the difficulty that remains in developing and adapting them locally. Facilitating collective management of resources and encouraging both their improvement and circulation will likely be important elements of any meaningful solution.

What do the snapshots of digital education resources tell us?

- **"Ubiquitous learning" affordance**: The review suggests that it would be useful to pay more attention to strategies for localization of the resources in terms of language and culture.
- "**Active knowledge making", "multimodal meaning" and "metacognition" affordances**: It will open up more pedagogical opportunities if digital education resources are considered not so much as a teaching machine but as an instrument for fostering learners' agency, creativity, critical thinking and critical engagement. Active knowledge making and multimodal meaning can be considered across the multiple contexts of learning — the classroom, the real world, and the digital world — to achieve real impact for students, communities, and the global commons as envisioned by SDG 4, especially Target 4.7.
- **"Recursive feedback" and "differentiated learning" affordances**: There is considerable scope to address this affordance more explicitly to develop assessment that promote learning from mistakes and foster deeper learning. In order to give every learner opportunities to find his or her own learning paths and realize his or her fullest potentials, a wider range of formative assessment processes can be embedded in resources, and the role of the teacher in the assessment process needs to be recalibrated.
- **"Collaborative intelligence" affordance**: Many of the digital education resources sampled for this review focus on individual knowledge acquisition. With notable exceptions, the social aspect of learning seems to be still unstructured and not facilitated for the learning process. In terms of the skills of empathy, changing perspectives and making discerning decisions, technology can play a crucial role by connecting learners, teachers and open opportunities for exchanging experiences.

- **"Accessibility" affordance**: To fully utilize the accessibility affordance of the digital technology, content creators should consider UDL design for the margins from the beginning of the design process to help remove barriers to inclusivity and participation. This affordance provides a fair entry point to participation in learning processes. Effective design for multiple demographics can reduce costs and the need for second round subtitling, transcribing videos, creation of podcasts for people with disabilities, and other forms of modified content provision.

Recommendations

- Align use of technology to pedagogical approaches rather than allowing technological limitations to determine pedagogy. Use technology to enhance active and meaningful engagement in learning.
- Align pedagogical approaches to a clear vision of the evolving purposes of education. As articulated in SDG 4.7, this purpose includes but goes well beyond instrumental career readiness and therefore requires pedagogies that support development of the knowledge, skills, attitudes and dispositions that will enable learners to contribute actively to SDG attainment.
- Transform the ends and processes of assessment as a fulcrum for pedagogical reform.
- Build capacity of resource developers, syllabus designers, education system administrators, digital and physical infrastructure planners.

Recommendation 3: Ensure that teachers keep digital educational resources alive for the benefit of students

Decision makers need to take into account that:

- Teachers play the active role with the students, managing activities with educational resources, which have to be adapted to a particular regions, groups, to the progression of individuals and the group (constant adaptation to a local context).
- The process of appropriation of resources by teachers is necessary and often a regular part of teacher's daily task.
- Integrating the constant renewal of knowledge in teaching is a challenging yet critical task of teachers. Isolated teachers in their classrooms may have difficulty coping with implementing ongoing transformation alone, and communities are required to facilitate transformation and communication between subjects as well as enhancing capacity building across locales.
- With regard to teacher training, whether pre-service or as continuing professional development, barriers include often significant costs and the necessity for regular updates in programming (due to changes in what needs to be learned and in learning environments). The solution to this issue is necessarily multifaceted. Forms of self-training are needed; but wherever possible, the nurturing of communities of practice, whether local or global, should be considered.

Key changes

- A more collective identity for teachers: less working alone and exchanging and participating in collectives. A more collective vision of the teaching profession recognizes both the diverse needs and contexts of teachers but also the shared aspirations, approaches, and potentially integrates the design, adaptation and sharing of educational resources.

- Teachers acting (individually and collectively) as learning designers and co-designers, producers or adapters of resources, with their critical role going beyond transmission of knowledge to orchestration, facilitation, accompaniment, “game masters” in the classroom
- Educational resources as “commons”, managed and curated by teachers, students and other stakeholders allowing the pools of resources alive and renewed. This would require explicit discussions of the need for ‘glocalization’ and contextualization as an ancillary.

Recommendations

- Ensure availability of pre- and in-service teacher training concerning creation or modification of resources: mixing teacher training and creation of scenarios and co-design with teachers. Generally speaking, collective and empowering visions of the teaching profession should be promoted. However, where possible, they can be supported by strategic capacity building and top-down initiatives. This top-down capacity building may be regional, national, or international in origin depending on the objectives. They could be analogue, digital, blended, autonomous, or facilitated.
- Identify, trial, and improve scalable capacity building measures for integrating subject specific teacher resource development with the aspirations of sustainable development. Both subject specific and interdisciplinary supports should be researched and evaluated for efficacy and cost effectiveness.
- Engage with and shape adaptive and customizable dashboards of learning data.
- Build teacher capacities to understand and address equity issues in learning with technology.
- Facilitate the formation of collective identity and responsibility of teachers through empowered agency at the local, regional, and global level. Examine ways to help teachers to organize collectively.

The New Roles of Teachers

- Teacher as learning designer, curating digital resources and designing activity sequences that create conditions for addressing sustainable development and global citizenship
- Teacher as data analyst, interpreting formative feedback, building summative progress analyses, in order to discern impact on learners
- Teacher as educational inquirer, action researcher, and reflective practitioner
- Teacher as experienced project manager/community activist where appropriate

4. Ways Forward

Based on a review of literature and diverse examples of digital education resources and their implementation, we have put together a set of principles and broad approaches to guide future actions on the use of digital technology in education. Three points should be noted.

First, these key recommendations were developed with K-12 education, particularly compulsory education, in mind. While many are also applicable to higher education and lifelong learning contexts, the recommendations focus primarily on the use of digital education media and resources in schools, rather than on distance learning or online courses in the post-secondary settings.

Second, given the first point, the recommendations focus on educational resources as support for school practices. What matters is not so much the particular features and functionalities of educational media and resources but teachers' negotiating and figuring out how a new technology or technology-mediated approach could be integrated into the complicated, multifaceted world of schools and day-to-day practices in classrooms.

Third, we need open, cross-sector dialogue and collaborative development of actionable, evolving guidelines for different stakeholder groups. For policymakers, such guidelines might help develop a clear vision of the purpose of introducing technology into the classrooms. For publishers, they might provide insights and concrete guides that would be useful for developing a new business model around digital textbooks. For developers of digital content, they might put forward a set of design principles which are adaptable to diverse contexts. For educators, such guidelines might propose developing teacher capacities to detect and address equity issues in learning with technology, or to synthesize emerging digital affordances with the authentic, student-centred pedagogical approaches. For all stakeholders, actionable guidelines should be underpinned by an enhanced awareness and understanding of sustainable development so that decisions, infrastructure, and resources are developed with broader societal outcomes in mind.

This publication is only the beginning. There is a need to reflect on the practical implications of implementing these key recommendations in different contexts. Given the very wide variety of contexts, which both constrain and facilitate the conditions under which learning can occur, it is not possible for us to provide prescriptive action guides to be applied. This report is for various stakeholders who will be able to negotiate and navigate the local conditions they know better than we do, to implement the key recommendations we have made. UNESCO (2005b) put forward a view of quality as indicative of the capacity of an educational system to improve itself. Our goal of producing this report will be achieved when the readers will be able to re-problematize and improve our proposals in their own context for the benefit of their students.

Appendices

Appendix I

List of Digital Education Resources Sampled

This list includes more than 80 resources sampled by the expert group convened by MGIEP, but more than a quarter of them are platforms, portals or repositories that include multiple independent resources. Where available, the number of resources hosted (as of 28 August 2019) is indicated in the description of the resources below.

Three of the resources in the list, namely GeoGebra, Code.org and TEMOA, each hosts more than one million resources. These high figures indicate that these are living resources, regularly used and updated. Code.org, with more than 52 million projects (resources) created on the platform, offers a good example of activities that can only be done using digital products. (In less than two months between 28 August 2019 and 21 October 2019, the number of projects created on Code.org increased by four million to reach 56 million.) It is important to note that Code.org is a platform for teaching and learning computer science, and GeoGebra is a mathematics software. This level of success would not have been possible for resources for subjects of less universal nature, say, history, languages or social studies, which depend greatly on local contexts. Even though the economic models of digital educational resources and digital textbooks have not yet stabilized, these figures show a significant increase in the use of digital educational resources.

Regarding digital textbooks for K-12 education, if we suppose that there is one textbook per subject and an average of 10 subjects in each grade, we can assume that 120 digital textbooks cover the entire K-12 curriculum. India's National Council of Educational Research and Training (NCERT) offers free access to the NCERT textbooks and other resources, especially for all subjects published by NCERT for classes I to XII in Hindi, English and Urdu. Given that it includes 454 textbooks in total, it clearly covers the entire curriculum. Although it lies beyond the scope of the current study, it would be interesting to launch a study on the economics of digital textbooks.

Several OER platforms are included in the list. For example, OER Africa hosts 492 resources, while a multilingual OER repository TEMOA from Mexico hosts 1,076,957 resources. Less than 500 resources indicate a still embryonic development. As the case of TEMOA (**Box 3-2**) shows, the management of OERs requires sufficient technical expertise and organization. Exceeding one million resources seems to be a good indication that the platform is regularly used.

The list also includes a number of MOOC platforms, and the scale of these varies; edX hosts 2,909 courses, while Coursera hosts 4,278. The offer of courses is steadily increasing, and some MOOCs allow people to obtain diplomas and certificates, indicating important evolutions in higher education. Udemy, which is not entirely a MOOC platform, hosts 130,000 courses, including MOOCs and other courses.

When available in the public domain and deemed useful, information on the country (and sometimes city, state or province) and year in which the resource was first published is indicated to give some idea on its provenance. For some commercial, open or closed access products developed by publishing houses, higher education institutions, IT or EdTech companies or public-private partnerships, the name(s) of the creator(s) of the resource is indicated as well.

(1) Digital textbooks

Languages and culture

Complete English Basics (Macmillan Education, 2017)
Complete English Basics series (Third Edition) was published in 2017 for Australian schools. This workbook series is designed to support junior to middle secondary students with essential language and literacy skills.

Ancient Greek for Everyone (2017)
Ancient Greek for Everyone by Wilfred E. Major and Michael Laughy is a digital (digitized) textbook created with Pressbooks (a simple book production software which allows the creations interactive web books, PDFs for print, and ebooks). It provides explanation and practice of the core of the ancient Greek language licensed under a Creative Commons.

Subject area non-specified

BiBox DEins 5 Gymnasium (WestermannGruppe, Germany, 2017)
BiBox DEins 5 Gymnasium is a digital textbook that offers a comprehensive digital package to supplement the paper textbook, with both online and offline content delivery. The e-book is available in two versions: a student version and a teacher version.

EduBook3D AULA. (E.S.O.) (Vicens Vives, 2015)
EduBook Classroom consists of various modules that allow the student to integrate into a virtual classroom of an educational center. The platform contains digital books, literature, languages, notebooks, classroom material, educational robots and children's books.

Repository of digital textbooks and eBooks

National Council of Educational Research and Training (NCERT) (India)
This is an online website that offers free access to the 454 textbooks and other resources published by NCERT, for all subjects for classes I to XII, in Hindi, English and Urdu.

BC Campus OpenEd (British Columbia, Canada, 2012)
BC Campus Open Ed hosts textbooks licensed under an open copyright license and made available online to be freely used by students, teachers and members of the public. The textbooks are available free as online versions, and as low-cost printed versions.

The Institutional Repository of Tecnológico de Monterrey (RITEC) (Mexico, 2002)
RITEC is a collection of open-access online resources that include a set of services that a university offers to members of its community for the management and dissemination of digital materials created by the institution and its community members. It includes 28,024 resources.

24grammata (Greece, 2019)
The 24grammata.com e-Magazine presents a unique collection of free eBooks on classical literature and history written in English. The collection is updated daily with new eBooks chosen by literature experts with the sole purpose of promoting universal classical literature. It includes 7,500 e-books.

BC Open Textbook Project (British Columbia, Canada, 2013)
The BC Open Textbook Collection is an open textbook database created or recreated by British Columbia, Canada, which focuses on the post-secondary level. Textbooks are available under a Creative Commons License, and it provides "home to a growing selection of open textbooks for a variety of subjects and specialties." The database contains 296 textbooks.

Biblioteca Vasconcelos (Mexico, 2006)
The Vasconcelos Library provides multi-media resources and is a public space of free access for anyone, regardless of ethnic or national origin, dress, age, social, economic, religious, gender, sexual preferences or subject to any other form of discrimination.

Biblioteca Digital de ILCE (Latin American Institute of Educational Communication – ILCE, Mexico)
The Digital Library of the ILCE is a free-access portal that offers works and collections of books for free access on the Internet. It presents general works on culture: literature, art, geography, history, scientific discovery, environmental education, pedagogy, dictionaries, games and songs, among others.

Camões Digital Library (Camões - Instituto da Cooperação e da Língua, Portugal, 2019)
The Camões Digital Library is a repository of the Portuguese language culture. Its main objective is to provide access to publications, texts and documents of great cultural and linguistic relevance. This digital library aims to bring Portuguese language and culture to an ever wider universe of Portuguese speakers and students.

Macmillan Education Everywhere (United Kingdom, 2011)
Macmillan Education is made up of three strands: Language Learning, Schools Curriculum and Higher Education. It aims to educate generations of communities through developing pioneering and forward-thinking educational materials for all.

Dirección General de Bibliotecas, UNAM (Autonomous National University of Mexico – UNAM, Mexico, 2010)
The digital library aims to become a leading organization and reference in information systems on documentary collections. The aim is to increase and innovate library and information services to the university community.

Macmillan Explorers (2017)
Macmillan Explorers is a subscription-based online archive of eTextbooks for university students and academics. The content includes textbooks of political science, computer science, history, literature and social work.

Macmillan Argentina (2000)
Macmillan Argentina is a catalogue of digital materials for different levels and needs. It includes resources on grammar and vocabulary, dictionaries and business, for children, teenagers and young adults.

(2) Multimodal resources

Multiple subject areas

Khan Academy (California, USA, 2007)
Khan Academy is an online platform that offers practice exercises, instructional videos, and a personalized learning dashboard that empower learners to study at their own pace in and outside of the classroom. It tackles math, science, computer programming, history, art history, economics, and more.

Language and culture

British Council Learning English Online (United Kingdom)
British Council's 'Learn English Online' webpage offers free online resources to help adults, including business professionals, teenagers and children learn English. The resources include videos, mobile apps, games, stories, listening activities, grammar exercises, and MOOCs online courses in partnership with FutureLearn.

Confucius Institute Online (China, 2009)
This is an online platform being developed with state support, which aims to provide online resources and interactive coursework for students and teachers of Mandarin. It includes 94 MOOCs.

Mathematics and statistics

Math is Fun
Math is Fun is an online math practice platform developed by IXL (immersive learning experience) Company. It covers from basic mathematical concepts such as numbers, to operations like measurement, algebra, geometry and advanced concepts of data, calculus and physics.

GeoGebra (Austria, 2001)
GeoGebra is a Dynamic Mathematics Software (DMS) for teaching and learning mathematics at all levels of education. GeoGebra is an interactive geometry, algebra, statistics and calculus application. It is available in 32 languages and is used by more than 100 million users around the world. It includes more than 1 million resources.

ImmersiveMath (2015)
The idea that the creator focuses on is to start each chapter with an intuitive concrete example that shows, using interactive illustrations, how the math works. The creator's premise is that it is easier to understand the entire topic of linear algebra with a simple and concrete example cemented into the reader's mind at the beginning of each chapter.

Math Insight (Minnesota, USA, 2015)
Math Insight aims to provide qualitative descriptions and interactive applets to explore mathematical concepts. It is an advanced mathematics resource targeting university-level learners. Its main focus is multivariable calculus. It also presents other topics covered by

vector algebra, elementary dynamical systems, assessments of elementary mathematics and mathematical modeling of biological systems.

MIT Mathlets (Massachusetts, USA, 2009)
The MIT Mathlets is "a suite of carefully designed and highly interactive Javascript applets" designed for students to learn about differential equations, calculus, probability and statistics. The Mathlets range from coordinate changes to Eigenvalue stability and linear programming to wave equation. It was designed specifically to assist university students with their Math topics.

The Parent's School (New Delhi, India)
It is a model of the next generation school system (virtual app) designed especially for parents. It contains Micro concepts mapped to the Central Board of Secondary Education (with additional concepts mapped to the International General Certificate of Secondary Education and Indian Certificate of Secondary Education) curriculum-based content (for class I to X Mathematics, Science and Social Science) woven with prior knowledge, practice exercises and activities to help children understand fundamentals of every concept.

PERFECTEN (New Delhi, India)
PERFECTEN is an app for teaching mathematics and science. It seeks to cultivate logical thinking and innovation. It maps the Class X mathematics and science syllabi, divided into over 235 learning outcomes (micro-concepts), to help students learn the exact things they need to know, focus upon, and prepare for the X Board Examinations.

Seeing Theory (2016)
Seeing Theory (created by Daniel Kunin) is a visual introduction to probability and statistics with a goal of making the concepts in these subjects more accessible through interactive visualizations. It is now available in Chinese and Spanish besides English.

Digital skills

Scratch (Massachusetts, USA, 2002)
Scratch is an open, interactive learning environment on the Web, designed for ages 8 to 16 but used by people of all ages. It is free of charge, and it helps users learn and improve programming skills, using the drag and drop technique to create interactive stories, games and animations of any topic.

DQ World (2010)
DQ World is an animated online game that intends to provide a fun and safe e-learning platform for children to be empowered with the 8 core 'digital intelligence' (DQ) competencies, including knowledge, skills, attitudes and values young people need to participate safely and responsibly in the online world. It includes 20 resources.

Code.org (USA, 2013)
Code.org is an online learning and teaching platform dedicated to expanding access to computer science in schools and to provide more opportunities to learn computer science. The platform provides a widely used curriculum in computer science education in primary and secondary school. More than 52 million projects (resources) have been created on this platform.

Blockly (USA, 2012)
Blockly is a web-based developer tool and open source library that allows users to create web and mobile apps dragging and dropping blocks, providing a friendly visual workspace while they learn and improve their programming skills.

Codecademy (USA, 2011)
Codecademy is an online platform that offers free coding classes for learning and practising several different programming languages such as Python, Java, JavaScript, Ruby, SQL, C++, and Sass, as well as markup languages HTML and CSS. There are no videos but it provides a direct user interface for learners to write codes.

@prende.mx (Mexico, 2015)
It was created with the objective of carrying out the planning, coordination, execution and periodic evaluation of the Digital Inclusion Program (PID). It seeks to promote literacy, and the incorporation of new information and communication technologies in the teaching-learning process.

Artificial Intelligence (for all learners)

Google.ai (USA, 2006)
Google.ai is a division of Google that serves as a portal for AI-related OERs, tools and research. It aims to enable students to sharpen their coding skills as machine learning practitioners, and provides information and exercises to help them develop new skills and advance their projects.

Microsoft professional program for AI (USA)
Microsoft professional program for AI is a compendium of courses designed to teach technology skills such as Python, Math, Azure Machine Learning, Computer Vision, Data Analysis, Natural Language Processing and Speech Recognition.

IBM Watson (USA)
IBM Watson was developed for students to experiment with AI tools and resources that are freely available through an IBM cloud account. Users are able to choose a starter kit and get access to a code and API credentials to get started, and then deploy their project on their own machines or onto IBM Cloud.

SDG 4.7-related (civics, education for sustainable development, global citizenship education)

iCivics (USA, 2009)
iCivics provides free online educational games and lesson plans to promote civics education and encourage students to become active citizens. The iCivics platform hosts 20 civics-themed video games, as well as paper-based activities and lesson plans. It has 110,000 registered educators. It is estimated that it is used by about half of all middle school social studies teachers in the United States.

Konsumspuren (Germany, 2019)
Konsumspuren is a portal of digital materials designed to teach 7-11 grade pupils how to protect the climate through the Consumption Traces interactive and action-oriented

module. Each lesson lasts from 45 to 180 minutes, and is adapted to the topics, interests and knowledge levels of the class.

ePals (Cricket Media, 2017)
ePals is an online platform where teachers and students (aged three to 19 years) from around the world can connect, communicate and collaborate on three broad experiences: language, cultural, and subject-based exchange. It allows moderated multiclass discussion board use and provides resources for project-based learning.

Resource for any subject

eKitabu (Kenya, 2012)
The educational impact of books is the foundation of eKitabu. It is re-designing the foundation with users and partners from public and private sector—to increase accessibility and lower the cost of content for quality education—sustainably and at large scale. eKitabu, through their open architecture, global collection of ebooks and ecosystem partners, lowers the cost of delivering accessible content for quality education in local languages.

FazGame (Brazil, 2012)
FazGame is portal that presents a fun and intuitive environment for creating games education and access to the games anytime and anywhere. During the process of creating games, it is expected that skills such as logical reasoning, problem-solving, creative thinking and collaboration can be learned in a fun and dynamic way.

Google Expeditions (2015)
Google built the Expeditions app and Cardboard viewer and Cardboard Camera "to bring immersive experiences" to schools through virtual expeditions to explore history, science, the arts and the natural world. Tours are premade or can be created using Google's Tour Creator, where teachers and students can make VR tours using footage from 360-degree cameras or Google Street View content.

Minecraft: Education Edition (2016)
Minecraft: Education Edition is an open-world game-based learning platform that promotes creativity, collaboration and problem-solving among students, in an immersive environment, through simple visual coding. . It provides content of math, science, language arts, history and visual art for K-12. Minecraft is supporting thousands of educators in more than 100 countries.

Sporcle (USA, 2007)
Sporcle provides trivia entertainment on the web, on mobile devices, and at live shows. The tool could be used in any class and any subject where some form of assessment is being used. It can be used to develop quizzes collaboratively or individually. It is an interactive tool for teachers or students to use in class to make classes fun.

TED-Ed (2012)
TED-Ed is an educational platform of a growing library of original animated videos. It allows the creation and customization of educational lessons. It has over 8.5 million subscribers, a global network of over 250,000 teachers and over 1.25 billion views as of February 2019. It includes 3,350 videos.

Assessment

Ontario Colleges Math Test (OCMT) (Vretta, Ministry of Education and Ministry of Training, Colleges and Universities in Ontario, Canada, 2013)
OCMT is a customized Assessment for Learning program that helps students identify and improve the key math skills they need to master to be successful in college. This project includes 24 Ontario colleges (22 English language and 2 French language colleges) and 72 Ontario school boards, reaching over 10,000 students in Ontario.

Repository of OERs

OER Africa (2008)
OER Africa is designed by the collaboration of four universities in Africa to establish networks of African OER practitioners to develop, share, and adapt OER to meet the education needs of African societies. The focus areas are agriculture, foundation skills, health and teacher education. It includes 492 resources.

TEMOA (Tecnológico de Monterrey, Mexico, 2002)
TEMOA is a resource repository that aims to provide a multilingual catalogue of OER to teachers for building or improving their course materials through a specialized and collaborative search system and social tools to promote knowledge transference and use of information technologies in education. It includes more than 1 million resources.

National Repository of Open Educational Resources (NROER) (Ministry of Human Resources Development, India, 2013)
NROER is a collaborative platform for school and teacher education. The content includes resources mapped to the National Curriculum Framework, an eLibrary and eCourses. The involved groups are individual and institutional partners, interest groups, schools, state partners and teachers. It hosts 14,422 resources.

Open Educational Resources (OER) Commons (ISKME: Institute for the Study of Knowledge Management in Education, USA, 2007)
OER Commons is a platform that provides access to open educational resources that are either in the public domain or are licensed under Creative Commons. It is a public database developed to serve curriculum experts and educators in discovering OER and collaborating around the use, evaluation and improvement of those materials. It hosts 81,172 OERs.

Biblioteca para ninõs "conoce tu mundo" (Tecnológico de Monterrey, Mexico, 2006)
The online library aims to present, in a systematic and simple way, the knowledge provided by the various sciences about the world in which we live. It is primarily aimed at children who attend the first years of basic education. Learners at the secondary school level can use the library to investigate and reinforce what they have learned in the classroom in relation to the area of knowledge of the environment.

CCA (Centros Comunitarios de Aprendizaje: Community Learning Centres) E-biblioteca (Tecnológico de Monterrey, Mexico)
This digital library provides slide shows embedded in the website on the themes of life, universe, basic concepts of astronomy and other topics for children, youth and adults. For

children and young people the subjects are related to the curricular contents mapped to different age groups; for adults they deal with themes dedicated to the family.

(3) Learning Environments

17zuoye (Shanghai, China, 2011)
17zuoye is the largest online learning platform for K-12 students, as well as teachers and parents in China. 17zuoye started as a tool for homework assistance but has since seen diversification of materials including digital online learning materials. It has over 60 million subscribed users of whom over 50 million are students from 140,000 schools in 365 cities across 31 provinces in China (17 Edtech Corporation, 2019).

BrainPOP (USA, 1999)
BrainPop is a group of educational websites with over 1,000 short animated movies for students in grades K-12 (ages 6 to 17), together with quizzes and related materials covering the subjects of science, social studies, English, mathematics, engineering and technology, health, and arts and music.

CK-12 (Palo Alto, California, USA, 2007)
CK-12 Foundation, which aims to increase access to low-cost K-12 education in the USA and abroad, provides a library of free online textbooks, videos, exercises, flashcards, and real world applications for over 5000 concepts from arithmetic to history. CK-12 was set up to support K-12 science, technology, engineering, and math (STEM) education.

ClassDojo (2011)
ClassDojo is a school communication platform (also available as a mobile app) that teachers, students and families use every day to build close-knit communities by sharing what is being learned in the classroom and home through photos, videos, and messages. It has been translated into 35 languages and has made inroads in 180 countries.

CENTURY (England, United Kingdom, 2013)
CENTURY aims to provide an LCMS (Learning-Content Management System) that streamlines initial knowledge acquisition to primarily support the British students who are underperforming, reduce the workload of the teachers and improve learning outcomes. The current version of the platform caters to the needs of students of grades 2 – 12 and in higher education, and its features can be customized as needed by clients.

MathemaTIC (Vretta, Canada and SCRIPT – Service de Coordination de la Recherche et de l'Innovation pédagogiques et technologiques, Ministry of National Education, Childhood and Youth, Luxembourg, 2015)
MathemaTIC is a personalized learning platform for students of primary and secondary schools to engage with interactive mathematical items mapped to their curriculum, and have fun learning mathematics. The platform also has a teachers' dashboard that provides intuitive visualizations of the data.

Oli.education.lu (OLI) (Ministry of National Education, Childhood and Youth, Luxembourg)
An online platform that provides an LMS, several digital resources, and other high-performance tools (tools to make the implementation of differentiated law easier, plus a whole host of e-Learning applications) for building websites for schools, classes and projects.

Nemzeti Köznevelési Portál (NKP) (Hungarian Institute for Educational Research and Development, Eszterházy Károly University)
NKP is a portal of digital learning materials. It cultivates students' digital competence and enables the creation of one's own curriculum, with different content for students, teachers and parents. The resources comprise subjects such as Hungarian grammar and literature, mathematics, morality, ethics, music, drama and dance, visual culture, physical education and sports, from Year 1 till 12 and 12+.

Profaxonline (Switzerland)
Profaxonline is a digital independent learning platform designed in accordance with Swiss school curriculum. It offers web-based training in mathematics, grammar and spelling, social science and perception skills. Teachers using Profaxonline are also supported with an LMS, which allows them to create work plans for the learners and follow their learning progress.

RIVED (Rede Interativa Virtual de Educacao) (Brazil, 1999)
RIVED is a program of the Brazilian Secretariat of Distance Education that aims to develop digital educational content as Learning Objects. The main goal of the project is to offer new teaching resources, in modules, to improve student learning in the classroom, and to make available a digital database that can be used by anyone interested in learning or teaching some basic content.

The Connected Learning Initiative (CLIx) (India, 2015)
CLIx is a technology-enabled initiative at scale primarily for high school students. It offers 15 modules containing more than 200 hours of learning content in the subject domains of digital literacy, English, mathematics, science and values education in English, Hindi and Telugu languages. These are being offered to students of government secondary schools in Chhattisgarh, Mizoram, Rajasthan and Telangana in their regional languages and have also been released as OER.

Schoology (2007)
Schoology is a free LMS. It allows educators to organize curriculum, create lesson plans and provide student assessment; and also to create and distribute materials, give assessments, attendance records, maintain an online gradebook, track students' progress and so on.

MOOC Platforms

National Public Platform of Education Resources (Ministry of Education of the People's Republic of China, 2012)
National Public Platform of Education Resources seeks to achieve 'Quality Resource Classes' and 'E-learning Space for Everyone' by providing multimedia, K-12 teacher resources and MOOCs.

iCourse (Beijing, China, 2011/2012)
A widely-used Chinese MOOCs platform created with the cooperation of the Chinese government, it has abundant courses that offer a free collection of lectures of university professors and vocational school teachers. Students can also participate in study sessions on the Internet. A service managed by a higher education publishing company belonging to the Chinese government, it enables everyone to share educational materials.

NetEase Open Courses (China, 2010)
NetEase Open Courses is available online and as an app, and is the largest provider of OER in China. By revising content and creating its own Online Open Courses NetEase hopes to leverage OER to connect China to the world and the world with China. It provides video tutorials (mostly free) from international as well as Chinese universities on subjects such as physics, mathematics, religion, and so on.

edX (Harvard University and MIT, 2012)
edX is home to more than 20 million learners, the majority of top-ranked universities in the world and industry-leading companies. As a global nonprofit, edX provides high-quality learning experiences including MicroMasters programs. It hosts 2,808 courses.

Udemy (2009)
Udemy is an online learning platform aimed at professional adults as a means of improving job-related skills. Unlike academic MOOC programs, which are driven by traditional collegiate coursework, Udemy uses content from online content creators to sell for profit. Udemy provides tools that enable users to create a course, promote it and earn money from student tuition charges. It hosts 130,000 courses (according to Wikipedia).

Coursera (Stanford University, 2012)
Coursera was founded in 2012 by two Stanford Computer Science professors who wanted to share their knowledge and skills with the world. Since then, anyone can use the platform anywhere and earn credentials from the world's top universities and education providers. Courses include recorded video lectures, auto-graded and peer-reviewed assignments, and community discussion forums. It hosts 4,278 MOOCs.

(4) Digital tools for teachers for designing educational resources or for evaluation

One Stop English (Springer Nature, 2000)
One Stop English is a teaching resource site of Macmillan Education. It houses over 9,000 resources based on age, level and language focus with audio and video lessons, games, songs and flashcards. It is "suitable for teachers of English as a foreign language (EFL), as a second language (ESL), as well as teachers of English for speakers of other languages (ESOL)".

e-Koolikott (Estonia, 2016)
The portal e-Koolikott allows easy access to digital learning materials and facilitates teachers to use materials from different websites, combine videos, games, worksheets and other educational tools, and make the created learning kits easily accessible for students and peers. It hosts 21,779 resources.

Educopédia (Brazil, 2010)
Educopédia is a platform of online digital classes for multiple subject areas developed by the Rio Municipal Department of Education in Brazil. It offers resources to support teachers, such as lesson plans, training courses, pedagogical games and videos, and other tools. These resources were produced by 300 teachers of the municipal network, based on the curricular guidelines.

Edpuzzle (USA, 2013)
This website allows one to make interactive video lessons and turn videos into formative assessments through simple editing tools. It offers a shared library of interactive video lessons, crowdsourcing its content from websites such as YouTube, Khan Academy and Ted Talks.

Dtab (Vretta, Canada, and the French Ministry of Education)
DTab is a large-scale interactive assessment platform aimed at assessing the performance of primary school students in an offline, mobile environment. This corresponds to the strategic vision of the French Ministry of Education to mainstream large-scale digital assessments for all primary school students across France.

MEC RED – Plataforma MEC de Recursos Educacionais Digitais (Brazilian Ministry of Education Platform of Digital Educational Resources)
MEC RED is an open integrated platform for digital educational resources serving as a search environment. It enables interaction and collaboration among teachers and allows them to save the resources in personal or public collections as needed. Users can also assign resources to colleagues via social networks, e-mail and the profiles on the platform. It hosts 31,598 resources.

Portal do Professor (Brazil, 2008)
Portal do Professor is an online community of teachers from all over Brazil to produce and share lesson suggestions, access information about educational practice, access and download multimedia resources, access study materials, interact and collaborate with other teachers, and access a collection of links.

Web radio and magazine

Science Friday (New York, USA, 1991)
The website has a partnership with educators and scientists to create free STEM activities and lessons for K-12 students, providing text, videos, animations and offline activities. Since 1991, they have been producing digital videos, audio podcasts and publishing original web content covering everything from octopus's camouflage to cooking on Mars.

Teacher magazine (Australia, 2017)
Teacher magazine is published by the Australian Council for Educational Research (ACER), a not-for-profit organization, which aims to promote quality teaching and leading, assisting school improvement at a grassroots level. It supports educators by providing timely, high quality, independent content such as articles, infographics, podcasts and videos.

Radio Mexico Internacional (IMER.MX) (Mexico, 2019)
It is the Internet station of the IMER, which also has an option to go on the air through Radio Digital in Mexico City and the metropolitan area. The main objective of the station is to talk about Mexico and be a window of the best of the country to the world, a link between the different regions and an option for rapprochement for Mexicans living abroad.

Appendix II:

Indicative Traits of the Eight Affordances of the 8A Framework

	Affordance	Indicators/enabling traits/dimensions
1	Ubiquitous Learning	1.1 Anytime, anywhere availability to broaden educational access 1.2 Blurring the traditional boundaries of space and time: extending the scope of learning beyond the walls of the classroom and the cells of the school timetable 1.3 Curriculum-community connections
2	Active Knowledge Making	2.1 Learners as designers of knowledge and meaning 2.2 Demonstrated capacity to collect information, conceptualize its meaning, think critically and apply in real contexts 2.3 Making knowledge artefacts: projects, objects, social interventions 2.4 Learners have autonomy, control and agency as knowledge creators 2.5 Discovery and exploration 2.6 Opportunities for innovation and creativity
3	Multimodal Meaning	3.1 Using a variety of modes of meaning (text, image, space, body, audio, simulations, virtual and augmented reality) 3.2 Making available a wide range of digital media resources 3.3 Supporting learners to make knowledge resources in a wide range of digital and non-digital media
4	Recursive Feedback	4.1 Appropriate feedback during learning, and feedback-on-feedback 4.2 Assessments for learning that promote learning from mistakes and foster deeper learning 4.3 Digital learning analytics 4.4 Peer review 4.5 Dashboard visualizations that make progress explicit to learners and teachers
5	Collaborative Intelligence	5.1 Peer-to-peer learning 5.2 Group activities and social networking 5.3 Distributed cognition: learning by thinking, aware of the social nature of knowledge 5.4 Acknowledging the community and intellectual provenance of information and concepts 5.5 Networks of knowledge and learning

	Affordance	Indicators/enabling traits/dimensions
6	Differentiated Learning	6.1 Variable learning paths 6.2 Adaptive and personalized learning 6.3 Self-regulation and self-management of learning 6.4 Recognizing learner diversity and harnessing diversity as a productive learning resource 6.5 Supporting students to express their own identities, develop personal pathways 6.6 Trust and open-ness: nurturing digital citizenship
7	Metacognition	7.1 Cognition = the empirical, the topic, the theme -- always linked to metacognition, hence multilevel thinking 7.2 Metacognition = the disciplinary framework, thinking conceptually/ theoretically, regulating one's own thinking processes 7.3 Linking concrete and particular to the abstract, general and conceptual 7.4 Complex problem solving, addressing challenges with holistic, mulitiperspectival thinking 7.5 Authentic learning, linking disciplinary practice to local and personal circumstances
8	Accessibility	8.1 Affordability (with Open Access as one option) 8.2 Ownership: credit to creators, whether resources are free or at a price 8.3 Interoperability, removing digital systems silos in a way that a system can freely communicate and operate with other external systems and thereby open to them 8.4 Hybrid deployment across multiple platforms, browsers, operating systems and devices in a way that an application or resource is accessible over more than one platform like Windows, Mac, Android, Unix and Ubuntu 8.5 Universal Design for Learning (UDL) requirements for disability accessibility 8.6 Internationalization of functionalities in all resources and their interfaces, facilitating ease of translation

References

Alemán de la Garza, L.Y., Sancho-Vinuesa, T. and Gómez-Zermeño, M.G. (2015) 'Indicators of pedagogical quality for the design of a massive open online course for teacher training', *RUSC Universities and Knowledge Society Journal,* 12(1), pp. 104-118.

Andrews, P. (2007) 'Conditions for learning: a footnote on pedagogy and didactics', *Mathematics Teaching Incorporating Micromath,* 204, pp. 22-23.

Anichini, A.S. and Parigi, C. (2016) 'Auto-produced textbooks: different approaches from the analysis of the experience of innovative Italian schools', *EDULEARN16 Proceedings,* pp. 5029-5036.

Antal P. and Kis-Tóth, L. (2015) 'Alsó tagozatos gyerekek olvasásértésének fejlesztése mobil infokommunikációs eszközökkel', in Zoltán, H. (ed.) *A pedagógusképzés megújítása.* Eger: Líceum Kiadó, pp. 259–280.

Attewell. P (2001) 'The first and second digital divides', *Sociology of Education,* 74 (3), pp. 252-259.

Azevedo, R. (2009) 'Theoretical, conceptual, methodological, and instructional issues in research on metacognition and self-regulated learning: a discussion', *Metacognition and Learning,* 4(1), pp. 87–95. http://sci-hub.tw/10.1007/s11409-009-9035-7.

Barab, S.A., Gresalfi, M. and Ingram-Goble, A. (2010) 'Transformational play: Using games to position person, content, and context', *Educational Researcher,* 39(7), pp. 525–536.

Baron, G.L. and Bruillard, É. (1996) *L'informatique et ses usagers dans l'éducation*. l'Éducateur. Paris: Presses Universitaires de France.

Baumann, Z. (2000) *Liquid modernity.* Polity Press.

Beauné, A., Levoin, X., Bruillard, É., Quentin, I. Zablot, S. *et al.* (2019) *Collectifs en réseau d'enseignants producteurs de ressources.* Rapport scientifique des laborat.02oires STEF et EDA. Convention DNE. [Rapport de recherche] Université Paris; ENS Cachan. https://hal.archives-ouvertes.fr/hal-02022830/file/rapport_final.pdf

Bell, K. (2017) *Game on!: gamification, gameful design, and the rise of the gamer educator.* Johns Hopkins University Press.

Bergviken Rensfeldt, A., Hillman, T. and Selwyn, N. (2018) 'Teachers "liking" their work? Exploring the realities of teacher Facebook groups', *British Educational Research Journal,* 44(2), pp. 230-250.

Bernstein, A., Bernstein, J., Lustig, M., Johnson, K., Peterson, J., Scott, Z., Stewart, K. and Strobach, K.V. (2019) *Title IV, part A of ESSA: Student Support and Academic Enrichments grants.* Washington, DC: Title IV-A Coalition. https://static1.squarespace.com/static/59397d27be65945cac3a63e8/t/5c61d7d1e2c4831e6d45ae55/1549916113275/Title+IV+Part+A+Fact++Sheet_January+2019.pdf

Bertrand, M., and Marsh, J. A. (2015) 'Teachers' sensemaking of data and implications for equity', *American Educational Research Journal,* 52(5), pp. 861–893.

Bettinger, E. and Loeb, S. (2017) *Promises and pitfalls of online education.* Evidence Speaks Reports, 2 (15), Economic Studies at Brookings. Washington DC: Brookings.

Blazer, C. (2013) *Literature review digital textbooks*. Research Services, Office of Assessment, Research, and Data Analysis, Miami-Dade County Public Schools. http://drs.dadeschools.net/AdditionalReports/LiteratureReviewonDigitalTextbooks.pdf

Blazar, D., Heller, B., Kane, T., Polikoff, M., Staiger, D., Carrell, S., Goldhaber, D., Harris, D., Rachel Hitch, R., Kristian, L., Holden, K.L. and Kurlaender, M. (2019) *Learning by the book: comparing math achievement growth by textbook in six Common Core states.* Research Report. Cambridge, Massachusetts: Center for Education Policy Research, Harvard University. https://cepr.harvard.edu/files/cepr/files/cepr-curriculum-report_learning-by-the-book.pdf

Bougon, G., de Castro Guerra, E., De Coninck, B., Gémy, C., Hache, S., Hache, K., Largillier, C. *et al.* (2013) *Sésamath : mode d'emploi*. Floss Manuals. https://fr.flossmanuals.net/sesamath-mode-demploi/introduction/

Broadband Commission for Sustainable Development (2017) *Working Group on Education: digital skills for life and work.* International Telecommunications Union (ITU) and UNESCO. https://broadbandcommission.org/Documents/publications/WG-Education-Report2017.pdf

Brown, A. (1987) 'Metacognition, executive control, self-regulation, and other more mysterious mechanisms', in Weinert, F.E. and Kluwe, R.H. (eds.) *Metacognition, motivation, and understanding.* Hillsdale, New Jersey: Lawrence Erlbaum Associates, pp. 65-116.

Brown, M., Dehoney, J. and Millichap, N. (2015) *The next generation digital learning environment: a report on research*. ELI Paper. https://library.educause.edu/~/media/files/library/2015/4/eli3035-pdf.pdf

Bruillard, É. (in press) 'Teaching machines', in Tatnall, A (ed.) *Encyclopaedia of education and information technologies.* Springer.

Bruillard, É. (2003) 'Textbooks and electronic resources for low secondary schools: an analysis of the French situation', in Horsley, M., Knudsen, S.V. and Selander, S. (eds.) *Has past passed? Textbooks and educational media for the 21st century.* Bratislava and Stockholm: Stockholm Institute of Press, pp.100-105. http://eda.recherche.parisdescartes.fr/wp-content/uploads/sites/6/2019/03/EB_Iartem_1.pdf

Bruillard, É. (2011) 'Current textbook research in France: an overview', *International Textbook Symposium, ITS 2011 Trends and prospects of textbook policies,* Seoul, Korea, 28 April 28 2011, pp. 120-133 (translation in Korean, pp. 134-148). https://pdfs.semanticscholar.org/45fc/5b3425dff9b3c79e7cc1536b2127763a32e3.pdf

Bruillard, É. (2015) 'Digital textbooks: current trends in secondary education in France', in Rodríguez, J.R., Bruillard, É. and Horsley, M. (eds.), *Digital textbooks: what's new?* Universidade de Santiago de Compostela, pp. 188-202. http://eda.recherche.parisdescartes.fr/wp-content/uploads/sites/6/2019/03/EB_digital_textbooks_vfin.pdf

Bruillard, É. (2017) 'MOOCs as contemporary forms of books: new educational services between control and conversation', *IARTEM e-Journal,* 9(1), pp.142-164. http://biriwa.com/iartem/ejournal/volume9.1/articles/article_7_bruillard_iartem_ej_2017.pdf

Bruillard É. (2019) 'Understanding teacher activity with educational resources: selection, creation, modification, use, discussion and sharing, in Rodríguez Rodríguez, J., Braga Garcia, Y.M. and Bruillard, É. (eds.) IARTEM 1991–2016: 25 years developing textbook and educational media research, pp. 343-352. https://iartemblog.files.wordpress.com/2019/09/iartem_25_years.pdf

Bruillard, É. and Baron, G.L. (1998) 'Vers des manuels électroniques ? Résultats d'une étude en mathématiques en classe de sixième', *Sciences et Techniques Éducatives,* 5(4), pp. 343-370.

Bruillard, É. and Baron, G.L. (2018) 'Researching the design and evaluation of information technology tools for education', in Voogt, J., Knezek, G., Christensen, R. and Lai, K.W. (eds.) *Second handbook of information technology in primary and secondary education.* Springer International Handbooks of Education Series. Springer. https://doi.org/10.1007/978-3-319-53803-7_79-1

Bryman, A. (2004) *Social research methods.* 2nd edn. New York: Oxford University Press.

Buck, G.H. (1989) 'Teaching machines and teaching aids in the ancient world', *McGill Journal of Education,* 24 (1), pp.31-54.

Buckingham, D. (2006) 'Defining digital literacy: what do young people need to know about digital media?', *Nordic Journal of Digital Literacy,* 9, pp. 21-34.

Bush, V. (1945) 'As we may think: a top U.S. scientist foresees a possible future world in which man-made machines start to think', *The Atlantic Monthly,* September 1945, pp. 112-124. [Online]. The condensed version of the original essay that appeared in the July 1945 issue re-published in the September 1945 issue of the Atlantic Monthly available at: http://worrydream.com/refs/Bush%20-%20As%20We%20May%20Think%20(Life%20Magazine%209-10-1945).pdf

Castañeda, L. and Selwyn, N. (2018) 'More than tools? Making sense of the ongoing digitizations of higher education', *International Journal of Educational Technology in Higher Education,* 15, Article number 22. doi: 10.1186/s41239-018-0109-y

Chabbott, C. (2007) 'Carrot soup, magic bullets, and scientific research for education and development', *Comparative Education Review,* 51(1), pp. 71-94.

Chaptal, A. (2009) 'Les cahiers 24x32. Mémoire sur la situation des TICE et quelques tendances internationales d'évolution', *Revue STICEF,* 16. http://sticef.univ-lemans.fr/num/vol2009/04-chaptal/sticef_2009_chaptal_04.htm

China Education Publishing and Media Group (2018) 中国教育出版传媒集团有限公司 [Online]. Available at: http://www.cepmg.com.cn/

Choppin, A. (1992) *Les manuels scolaires: histoire et actualité*. Paris: Hachette éducation.

Choppin, A. (2005) *Le manuel scolaire: Quels choix pour quels usages ? Approche historique.* Paris: Savoir Livre.

Choppin, A. (2008) 'Le manuel scolaire, une fausse évidence historique', *Histoire de l'éducation,* 117, pp. 7-56. http://journals.openedition.org/histoire-education/565

Collins, A. and Halverson, R. (2009) *Rethinking education in the age of technology: the digital revolution and the schools.* New York: Teachers College Press.

Connecticut Commission for Educational Technology (2016) Digital Learning Standards [Online]. Available at: https://www.ct.gov/iste

Connecticut Department of Education (2018) *International Society for Technology in Education* [Online]. Available at: https://portal.ct.gov/SDE/ISTE/International-Society-for-Technology-in-Education

Conole, G. and Brown, M. (2018) 'Reflecting on the impact of the Open Education Movement', *Journal of Learning for Development,* 5(3), pp. 187-203.

Cope, B. and Kalantzis, M. (2016) 'Big data comes to school: implications for learning, assessment and research', *AERA Open,* 2(2), pp. 1-19.

Cope, B. and Kalantzis, M. (2017) *e-Learning Ecologies*. New York: Routledge.

Cope, B. and Kalantzis, M. (2019) 'Education 2.0: artificial intelligence and the end of the test', *Beijing International Review of Education,* 1, pp. 528-543.

Crawford, K. (2003) 'The role and purpose of textbooks', *International Journal of Historical Learning, Teaching and Research,* 3(2), pp. 5-10.

Crowder, N.A. (1958) *L'arithmétique des ordinateurs, cours d'instruction programmée*. TutorText, Editions Gamma, traduction française, 1966.

Csikszentmihalyi, M. (1991) *Flow: the psychology of optimal experience*. New York: Harper Collins.

Csikszentmihalyi, M. (1997) *Creativity: flow and the psychology of discovery and invention*. New York: Harper Perennial.

Cuban, L. (1986) *Teachers and machines: the classroom use of technology since 1920*. New York: Teachers College Press Columbia University.

Cuban, L. (2001) *Oversold and underused: computers in the classroom.* Cambridge, Massachusetts: Harvard University Press.

Cuban, L. and Jandrić, P. (2015) 'The dubious promise of educational technologies: historical patterns and future challenges', *E-Learning and Digital Media,* 12 (3-5), pp. 425-439.

D'Avila, C. (2001) 'Le manuel scolaire brésilien : allié ou vilain dans la classe', in *Le manuel scolaire et l'intervention éducative : regards critiques sur ses apports et ses limites.* Sherbrooke: Éditions du CRP, pp. 115-143.

Dabbagh, N., and Kitsantas, A. (2012) 'Personal learning environments, social media, and self-regulated learning: a natural formula for connecting formal and informal learning', *The Internet and Higher Education,* 15(1), 3–8.

Dewey, J. (1916) *Democracy and Education: An Introduction to the Philosophy of Education.* New York: MacMillan.

Dolan, P., Leat, D., Mazzoli Smith, L., Mitra, S. and Todd, L. (2013) 'Self-organised learning environments (SOLEs) in an English school: an example of transformative pedagogy?', *Online Educational Research Journal,* 3(11), pp. 1-19.

Downes, S. (2010) 'New technology supporting informal learning', *Journal of Emerging Technologies in Web Intelligence,* 2(1), pp. 27-33.

Drescher, P. (2017) *The Vermont digital learning plan: 2018-2021.* Barre, VT: Vermont Agency of Education. https://education.vermont.gov/sites/aoe/files/documents/edu-education-technology-digital-learning-plan-draft.pdf

Dron, J. and Ardito, G. (2018) 'Open education resources, massive open online courses, and online platforms for distance and flexible learning', in Voogt, J., Knezek, G., Christensen, R. and Lai, K.W. (eds.) *Second handbook of information technology in primary and secondary Education.* Springer International Handbooks of Education Series. Springer. https://doi.org/10.1007/978-3-319-53803-7_47-2

Durlak, J.A., Weissberg, R.P., Dymnicki, A.B., Taylor, R.D. and Schellinger, K.B. (2011) 'The impact of enhancing students' social and emotional learning: a meta-analysis of school-based universal interventions', *Child development,* 82(1), pp. 405-432.

Eco, U. (1996) 'The future of the book (Afterword)', in Nunberg, G. (ed.) *The Future of the Book.* Berkeley: University of California Press, pp. 295-306. https://is.muni.cz/el/1421/podzim2007/IM002/um/Eco_-_The_Future_of_the_Book.pdf

Eicher, B., Polepeddi, L. and Goel, A. (2018) 'Jill Watson doesn't care if you're pregnant: grounding AI ethics in empirical studies', in *Proceedings of the 2018 AAAI/ACM Conference on Artificial Intelligence, Ethics, and Society,* New Orleans, USA, 13 February 2018, pp.88-94.

Engagement Global (2018) *Orientation needed: ESD in a digital world.* Discussion paper on mutually complementing Education for Sustainable Development and Digital Education at schools. Tulpenfeld: Engagement Global gGmbh.

Engelbart, D.C. (1962) *Augmenting human intellect: a conceptual framework.* Stanford Research Institute (SRI) Report. https://www.dougengelbart.org/content/view/138

European Commission (2019) *Strategic Framework for European Cooperation in Education and Training (ET 2020) Newsletter,* June 2019 edition. https://ec.europa.eu/education/sites/education/files/document-library-docs/et-2020-newsletter-june-2019.pdf

Falquet G., Nerima, L. and Ziswiler, J.C. (2009) 'Hyperbooks', in Kruk, S.R. and McDaniel, B. (eds.) *Semantic digital libraries.* Berlin, Heidelberg: Springer, pp. 179-196.

Falquet, G., Nerima, L., Hurni, J.P. and Guyot, J. (2001) 'Learning by creating multipoint of view scientific hyperbooks', in Dillenbourg, P., Eurelings, A. and Hakkarainen, K. (eds.) *First European Conference on Computer-Supported Collaborative Learning Euro-CSCL 2001,* Maastricht, The Netherland, pp. 222-229.

Farber, M. and Schrier, K. (2017) *The strengths and limitations of using digital games as "empathy" machines.* Working Paper. New Delhi: UNESCO MGIEP.

Fernandez-Duque, D., Baird, J.A. and Posner, M.I. (2000) 'Executive attention and metacognitive regulation', *Consciousness and Cognition,* 9(2), pp. 288-307.

Fernández López, J.M., Gómez Zermeño, M.G. and Pintor Chávez, M.M. (2016) *Development of policies for a digital repository for a higher education institution with technological disadvantages.* Education Policy Analysis Archives. http://dx.doi.org/10.14507/epaa.24.1806

Ferster, B. (2014) *Teaching machines: learning from the intersection of education and technology.* Baltimore: John Hopkins University Press.

Flavell, J.H. (1979) 'Metacognition and cognitive monitoring: a new area of cognitive–developmental inquiry', *American Psychologist,* 34(10), pp. 906-911.

Fredriksen, B.J., Brar, S. and Trucano, M. (2015) *Getting textbooks to every child in Sub-Saharan Africa: strategies for addressing the high cost and low availability problem.* Washington DC: World Bank.

Freinet, C. (1928) *Plus de manuels scolaires. Méthode vivante et rationnelle de travail scolaire par l'Imprimerie à l'École.* St. Paul: Éditions de l'Imprimerie à l'École.

Freinet, C. (1963) *Les boîtes enseignantes.* Autocorrection et programmation. Dossier pédagogique de l'Ecole moderne n°1. Supplément au numéro 2 du 1er octobre 1963. https://www.icem-pedagogie-freinet.org/node/15504

Freinet, C. (1964a) *Plus de manuels scolaires ! Plus de leçons !* Les Dossiers Pédagogiques de l'Educateur n° 7. Supplement au numero 6-15 novembre 1964. https://www.icem-pedagogie-freinet.org/node/15562

Freinet, C. (1964b) *Bandes enseignantes et programmation*. Bibliothèque de l'école moderne. N°29-32 septembre 1964. Deuxième édition septembre 1966. https://www.icem-pedagogie-freinet.org/node/18356

Gibboney, R.A. (2006) 'Intelligence by design: Thorndike versus Dewey', *Phi Delta Kappan,* 88(2), pp. 170-172.

Glasgow, R. E. and Emmons, K. M. (2007) 'How can we increase translation of research into practice? Types of evidence needed', *Annual Review of Public Health,* 28, pp. 413–433.

Glasser, H. (2019) 'Toward robust foundations for sustainable well-being societies: learning to change by changing how we learn', in Cook, J. (ed.) *Sustainability, human well-being, and the future of education.* Cham: Palgrave Macmillan, pp. 31-89.

Goel, A.K. and Polepeddi, L. (2016) *Jill Watson: A Virtual Teaching Assistant for Online Education* [Online]. Available at: https://smartech.gatech.edu/handle/1853/59104

Gómez-Zermeño, M.G. (2012) 'Bibliotecas digitales: recursos bibliográficos electrónicos en educación básica Digital libraries: electronic bibliographic resources on basic education]', *Comunicar,* 39, pp. 119-128.

Gómez-Zermeño. M. G. and Franco-Gutierrez, H. (2018) 'The use of educational platforms as teaching resource in mathematics', *Journal of Technology and Science Education,* 8(1), pp. 63-71.

Graesser, A.C. (2016) Conversations with AutoTutor help students learn. *International Journal of Artificial Intelligence in Education,* 26(1), pp. 124–132.

Graesser, A.C., Lu, S., Jackson, G.T., Mitchell, H.H., Ventura, M., Olney, A.M. and Louwerse, M.M. (2004) 'AutoTutor: a tutor with dialogue in natural language', *Behavior Research Methods, Instruments, and Computers,* 36, pp.180-193.

Graesser, A.C., Person, N.K., Harter, D. and Tutoring Research Group (2001) 'Teaching tactics and dialog in AutoTutor', *International Journal of Artificial Intelligence in Education,* 12(3), pp. 257-279.

Hache, S. (2018) *Réaliser des manuels sous licence libre—Retours d'expériences*. Manuel libre pour logiciel libre. Floss Manualsfr [Online]. Available at: https://www.flossmanualsfr.net/media/files/realiser-des-manuels-sous-licence-libre-retours-dexperiences/realiser-des-manuels-sous-licence-libre-retours-dexperiences.web.pdf

Hansen, J.D. and Reich, J. (2015) 'Democratizing education? Examining access and usage patterns in Massive Open Online Courses', *Science,* 350 (6265), pp. 1245-1248.

Harris, D. (2018) 'HCES STEM club uses 3-D printer to help student learn to communicate', *Daily Tribune News*, 29 October [Online]. Available at: http://www.daily-tribune.com/stories/hces-stemclub-uses-3-d-printer-to-help-student-learn-to-communicate,20392

Hegarty, B. (2015) 'Attributes of open pedagogy: a model for using open educational resources', *Educational Technology Magazine,* 55(4), pp. 3–13.

Herr Stephenson, B., Rhoten, D., Perkel, D. and Sims, C. (2011) *Digital Media and Technology in Afterschool Programs, Libraries, and Museums.* Cambridge, Massachusetts: MIT Press.

Herzog C. and Racsko, R. (2015) 'Egy táblagéppel támogatott pedagógiai kísérlet tanulói és szülői háttérvizsgálata', in Torgyik, J. (ed.) *Százarcú pedagógia.* Komarno: International Research Institute, pp. 81–94.

Higher Education Press (2018) 高等教育出版社简介 [Online]. Available at: http://www.hep.com.cn/aboutus/intro

Hodgkinson-Williams, C. and Trotter, H. (2018) 'A social justice framework for understanding open educational resources and practices in the Global South', *Journal of Learning for Development,* 5(3), pp. 204-224.

Hodgkinson-Williams, C., Arinto, P.B., Cartmill, T. and King, T. (2017) 'Factors influencing open educational practices and OER in the Global South: meta-synthesis of the ROER4D project', in Hodgkinson-Williams, C. and Arinto, P.B (eds.) *Adoption and impact of OER in the Global South.* Cape Town and Ottawa: African Minds, International Development Research Centre (IDRC) and Research on Open Educational Resources for Development (ROER4D), pp. 27–67. https://doi.org/10.5281/zenodo.1037088

Hofer, B. K. (2004) 'Epistemological understanding as a metacognitive process: thinking aloud during online searching', *Educational Psychologist,* 39(1), pp. 43-55.

Hoel, T. (2015) *e-Schoolbag in China – exploring research evidence for large scale deployment of e-Textbooks and services* [Online]. Available at: https://www.estandard.no/files/Hoel_ICALT_2015_submitted.pdf (prepared for the 15th IEEE International Conference on Advanced Learning Technologies ICALT 2015)

Holmes, W., Anastopoulou, S., Schaumburg, H. and Mavrikis, M. (2018) Technology-enhanced personalised learning: untangling the evidence. Stuttgart, Germany: Robert Bosch Stiftung.

Hoosen, S. and Butcher, N. (2019) *Understanding the impact of OER: achievements and challenges.* Moscow: UNESCO Institute for Information Technologies in Education (IITE). https://iite.unesco.org/wp-content/uploads/2019/04/Understanding_the_impact_of_OER_2019_final.pdf

Huang, Q. (2015) 'Digital Transformation of Education Publishing in China', *Publishing Research Quarterly,* 31(4), pp. 258–263.

Huffaker, D.A. and Calvert, S.L. (2003) 'The new science of learning: active learning, metacognition, and transfer of knowledge in e-learning applications', *Journal of Educational Computing Research,* 29(3), pp. 325-334.

Humphrey, N. (2013) *Social and emotional learning: a critical appraisal*. London: Sage Publications.

Inamorato dos Santos, A., Punie, Y., Castaño-Muñoz, J. (2016) *Opening up education: a support framework for higher education institutions.* JRC Science for Policy Report, EUR 27938 EN; doi:10.2791/293408

International Commission on the Development of Education (1972) *Learning to be: the world of education today and tomorrow*. Paris: UNESCO.

International Commission on Education for the Twenty-first Century (1996) *Learning: the treasure within.* Paris and London: UNESCO/HMSO.

Isin, E. and Ruppert, E. (2015) *Being digital citizens*. London: Rowman and Littlefield.

ISTE (2018a) *Creating systems of sustainability: four focus areas for the future of pk-12 open educational resources*. Arlington, VA: International Society for Technology in Education (ISTE). https://cdn.iste.org/www-root/Libraries/Documents%20%26%20Files/PDFs/new-america_oer_sustainability-research-paper_9-2018_v3_color_web.pdf?_ga=2.9332789.1046967710.1554405503-623015723.1536263814

ISTE (2018b) *Using ESSA to fund edtech: getting the most out of Title IV-A.* Arlington, VA: International Society for Technology in Education (ISTE). https://drive.google.com/file/d/1nEMubq-D2b3DWfPzMaveEbvjonC0x6J8/view

Ito, M., Baumer, S., Bittanti, M., boyd, d., Cody, R., Herr Stephenson, B., Horst, H.A., Lange, P.G., Mahendran, D., Martínez, K.Z., Pascoe, C.J., Perkel, D., Robinson, L., Sims, C. and Tripp, L. (2009) *Hanging Out, Messing Around, and Geeking Out: kids living and learning with new media.* Cambridge, Massachusetts: MIT Press.

Jenkins, H., Clinton, K., Purushotma, A., Robison, J. and Weigel, M. (2006) *Confronting the challenges of participatory culture: media education of the 21st century*. Chicago: The MacArthur Foundation. https://www.macfound.org/media/article_pdfs/JENKINS_WHITE_PAPER.PDF

Johnsen, E.B. (1993) *Textbooks in the kaleidoscope: a critical survey of literature and research on educational texts*. Oslo: Scandinavian University Press. http://www-bib.hive.no/tekster/pedtekst/kaleidoscope/forside.html

Joldersma, C.W. (2017) *Neuroscience and education: a philosophical appraisal*. Routledge.

Kafai, Y. and Burke, Q. (2013) 'Computer programming goes back to school', *Phi Delta Kappan,* 95(1), pp. 61-65.

Kalantzis, M. and Cope, B. (2015) 'Learning and new media', in Scott, D. and Hargreaves, H. (eds.) *The SAGE handbook of learning.* SAGE Publications, pp. 373-387. doi: http://dx.doi.org/10.4135/9781473915213.n35

Kalantzis, M., Cope, B., Chan, E. and Dalley-Trim, L. (2016) *Literacies.* 2nd edn. Cambridge UK: Cambridge University Press.

Kay, A. (1972) *A personal computer for children of all ages. Alan Kay's initial description of a "Dynabook" written at Xerox PARC in 1972*. VPRI Paper for Historical Context. http://www.vpri.org/pdf/hc_pers_comp_for_children.pdf

Kay, A. and Goldberg, A. (1977) 'Personal dynamic media', *Computer,* 10(3), pp. 31-41. doi: 10.1109/C-M.1977.217672

Kis-Tóth, L., Borbás, L. and Kárpáti, A. (2014) 'Táblagépek alkalmazása az oktatásban*:* tanári tapasztalatok', *Iskolakultúra,* 24(9), pp. 50-71.

Kis-Tóth, L., Fülep, A. and Racsko, R. (2013*) E-papír kísérletek a hazai közoktatásban.* Neveléstudomány: oktatás, kutatás, innováció 1, pp. 107–123. http://nevelestudomany.elte.hu/downloads/2013/nevelestudomany_2013_1

Kizilcec, R.F., Saltarelli, A.J., Reich, J. and Cohen, G.L. (2017) 'Closing global achievement gaps in MOOCs', *Science,* 355(6322), pp. 251-252.

Klein, A. (2019, 1 October) 'Ed-Tech usage levels are low: what should schools do?', *Education Week* [Online]. Available at: https://www.edweek.org/ew/articles/technology/2019/10/02/ed-tech-usage-levels-are-low-what-should.html

Koedinger, K.R., Anderson, J.R., Hadley, W.H. and Mark, M.A. (1987) 'Intelligent tutoring goes to school in the big city', *International Journal of Artificial Intelligence in Education,* 8, pp. 30-43.

Koehler, M.J., Mishra, P. and Cain, W. (2013) 'What is Technological Pedagogical Content Knowledge (TPACK)?', *Journal of Education,* 193 (3), pp. 13-19.

Kojanitz, L. (2019) 'Textbook development with the involvement of teachers', in Bruillard, É., Anichini, A. and Baron G.L. (eds.) *Changing media – changing schools? IARTEM 2017, 14th International Conference on Research on Textbooks and Educational,* Lisbon, Portugal, 27-29 September 2017, pp. 79-83.

Lagemann, E.C. (1989) The plural worlds of educational research. *History of Education Quarterly,* 29(2), pp. 183-214.

Lantz-Andersson, A., Lundin, M. and Selwyn, N. (2018) 'Twenty years of online teacher communities: a systematic review of formally-organized and informally-developed professional learning groups', *Teaching and Teacher Education,* 75, pp. 302-315.

Lebert, M. (2008) *Project Gutenberg (1971-2008)* [Online]. Available at: http://www.gutenberg.org/cache/epub/27045/pg27045-images.html

Levoin, X. (2018) *Mutations dans le paysage des ressources numériques à la lumière des BRNE.* Synthèse de l'enquête BRNE 2018. ÉDA, Université Paris Descartes sous la direction d'Éric Bruillard, novembre 2018. http://eda.recherche.parisdescartes.fr/wp-content/uploads/sites/6/2019/03/rapport_2018_v3.pdf

Liu, A. (2011) 'This is not a book: long forms of shared attention in the digital age', *Unbound Book Conference,* Central Library, Amsterdam, and Royal Library, The Hague, 20 May 2011. https://liu.english.ucsb.edu/this-is-not-a-book-long-forms-of-shared-attention-in-the-digital-age-unbound-book-conference-amsterdam-the-hague/

Liu, A. (2012a) *Translitteraties : le big bang de la lecture en ligne*. INA, e-dossiers de l'audiovisuel. https://escholarship.org/uc/item/7827v5wg#page-1

Liu, A. (2012b) 'This is not a book: transliteracies and long forms of digital attention', *Translittératies Conference,* École normale supérieure de Cachan, Paris, 7 November 2012.http://liu.english.ucsb.edu/this-is-not-a-book-translitteraties-conference-paris/

Livingston, J.A. (2003) 'Metacognition: an overview', *Psychology,* 13, pp. 259-266.

Lockee, M., Moore, M. and Burton, J. (2001) 'Old concerns with New Distance Education Research: Media comparison studies have fatal flaws that taint distance learning research relying on this strategy', *Educause Quarterly,* (2), pp. 60-62.

López Martínez, E., García Mejía, I.A. and Gómez-Zermeño, M.G. (2016) 'The integration of open educational resources to the mathematics curriculum: experiences of students and teachers of secondary education in Mexico', *Pedagogika,* 122(2), pp. 94–109.

Luo, Y. (2019) Email communication with Deng Chen, 9 April.

Lyon, A.R., Cook, C.R., Brown, E.C., Locke, J., Davis, C., Ehrhart, M., Aarons, G.A. (2018) 'Assessing organizational implementation context in the education sector: confirmatory factor analysis of measures of implementation leadership, climate, and citizenship', *Implementation Science,* 13, Article number 5. doi: 10.1186/s13012-017-0705-6

Mandinach, E.B. & Jimerson, J.B. (2016) 'Teachers learning how to use data: a synthesis of the issues and what is known', *Teaching and Teacher Education*: *An International Journal of Research and Studies,* 60, pp. 452-457.

Marcé, S. (2003) 'Évolution des rapports entre les enseignants et les professionnels de l'édition', in Baldner, J.M., Baron, G.L. and Bruillard, É. (eds.) (2003) *Les manuels à l'heure des technologies: r*ésultats de recherches en *college.* Paris: INRP, pp.117-120. http://eda.recherche.parisdescartes.fr/wp-content/uploads/sites/6/2019/03/Usage-ok.pdf

Mayer, R. (2004) 'Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction', *American Psychologist,* 59(1), 14–19.

Mayer, R. (2019) 'Computer games in education', *Annual Review of Psychology,* 70, 531–49.

Mcalister, A. and Horan, E. (2017) 'Acceleration of e-Learning in Australia and impacts of e-waste: Approaches to reforming e-Learning in the 21st century', in Pixel (ed.) *Proceedings of the 7th International Conference on the Future of Education*, Florence, Italy, 8-9 June 2017, pp. 63-66.

Means, B. (2010) 'Technology and education change: focus on student learning', *The Journal of Research on Technology in Education,* 42(3), 285–307.

Means, B., Toyama, Y., Murphy, R., Bakia, M. and Jones, K. (2010) *Evaluation of evidence-based practices in online learning: a meta-analysis and review of online learning studies*. Washington DC: US Department of Education, Office of Planning, Evaluation, and Policy Development, Policy and Program Studies Service.

MEC - Ministério da Educação. (2017) *Plataforma Integrada MEC de Recursos Educacionais Digitais: Informações Básicas* [Online]. Available at: http://portal.mec.gov.br/index.php?option=com_docman&view=download&alias=77031-informacoesbasicas-plataformaintegrada-seb-pdf&category_slug=novembro-2017-pdf&Itemid=30192

MEC - Ministério da Educação. (2018) *Plataforma de Recursos Educacionais ganha novos colaboradores e será ainda mais útil ao professor* [Online]. Available at: http://portal.mec.gov.br/ultimas-noticias/211-218175739/63331-plataforma-de-recursos-educacionais-ganha-novos-colaboradores-e-sera-ainda-mais-util-ao-professor

Ministry of Education of the People's Republic of China (2011) *Ten-year development plan of education informatization (2011–2020).* Beijing, China: People's Education Press.

Ministry of Education of the People's Republic of China (2018) *Implementation plan on prevention and control of nearsightedness in students in primary and secondary school.* Beijing, China: People's Education Press.

Moir, T (2018) 'Why is implementation science important for intervention design and evaluation within educational settings?', *Frontiers in Education,* 3, Article 61. doi: 10.3389/feduc.2018.00061

Moletsane, R. and Venter, C. (2018) 'The 21st century learning environment tools as electronic waste', in *Proceedings of the World Congress on Engineering and Computer Science 2018 Vol I WCECS 2018*, San Francisco, USA, 23-25 October 2018, pp. 188-192.

Moore, A., and Malinowski, P. (2009) 'Meditation, mindfulness and cognitive flexibility', *Consciousness and Cognition,* 18(1), pp. 176-186.

Naughton, J. (2016) 'The evolution of the Internet: from military experiment to general purpose technology', *Journal of Cyber Policy,* 1(1), 5-28.

Nebel, S., Schneider, S. and Rey, G.D. (2016) 'Mining learning and crafting scientific experiments: a literature review on the use of minecraft in education and research', *Educational Technology and Society,* 19 (2), pp. 355–366.

Nelson, T.H. (1965) 'Complex information processing: a file structure for the complex, the changing and the indeterminate', in *Proceedings of the 1965 20th National Conference of the Association of Computing Machinery (ACM '65)*, Cleveland, Ohio, USA, 24-26 August 1965, pp. 84-100. https://dl.acm.org/citation.cfm?id=806036

Nelson, T.H. (1970) 'No more teacher's dirty looks', *Computer Decisions,* 9(8), pp. 16–23. Reprinted in *Dream Machines*, Self-published, 1974. DM 16-19. Reprinted in *The New Media Reader*. Nick Montfort and Noah Wardrup-Fruin (eds.) Cambridge, Massachusetts: MIT Press, 2003 http://www.newmediareader.com/book_samples/nmr-21-nelson.pdf

Nguyen, T and Bruillard, É. (2011) 'Exchanging digital educational resources among teachers: a survey in Vietnam', *Society for Information Technology and Teacher Education, 22nd Annual Conference SITE 2011,* Nashville, 7-11 March 2011 [Online]. Available at: https://pdfs.semanticscholar.org/a187/67ae4e9c8e783a4dae8060ceecd23abe7f1a.pdf

Niyozov, S., and Dastambuev, N. (2012) 'Exploiting globalization while being exploited by it: insights from post-Soviet education reforms in Central Asia', *Comparative and International Education,* 41(3), Article 3. https://ir.lib.uwo.ca/cgi/viewcontent.cgi?article=1178&context=cie-eci

Nozaki, Y. (2008) *War memory, nationalism and education in postwar Japan, 1945–2007: the Japanese history textbook controversy and Ienaga Saburo's court challenges*. New York: Routledge.

Nye, B.D., Graesser, A.C. and Hu, X. (2014) 'AutoTutor and family: A review of 17 years of natural language tutoring', *International Journal of Artificial Intelligence in Education,* 24(4), pp. 427-469.

OECD (2015) *Students, computers and learning: making the connection*. PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264239555-en

OET (Office of Educational Technology) (2017a) *Reimagining the role of technology in education: 2017 National Education Technology Plan update*. Washington, DC: U.S. Department of Education. https://tech.ed.gov/files/2017/01/NETP17.pdf

OET (Office of Educational Technology) (2017b) *#GoOpen district launch packet*. Washington, D.C.: U.S. Department of Education. https://tech.ed.gov/files/2017/03/GoOpen-District-Launch-Packet-2017-V-1.3.pdf

Oliver, M. (2005) 'The problem with affordance', *E-Learning,* 2(4), pp. 402-413.

Paavola, S., and Hakkarainen, K. (2005) 'The knowledge creation metaphor: an emergent epistemological approach to learning', *Science and Education,* 14(6), pp. 535–557.

Pane, J.F. (2018) *Strategies for implementing personalized learning while evidence and resources are underdeveloped.* Santa Monica, CA: Rand Cooperation. https://www.rand.org/pubs/perspectives/PE314.html

Papert, S. (1980) *Mindstorms: children, computers and powerful Ideas.* New York: Basic Books.

People's Education Press (2018) 人民教育出版社 [Online]. Available at: http://www.pep.com.cn/rjgl/rjjj/201112/t20111221_1089877.shtml

Pettini, A., Ciari, B., Lodi, M., Bonaiuti, R., Tosi, L., Casanova, I., Dellacasa, R., and Daria, R. (1974) *Il libro di testo nella didattica moderna.* Firenze (Florence, Italy): La Nuova Italia.

Pressley, M., Borkowski, J.G. and Schneider, W. (2010) 'Cognitive strategies: good strategy users coordinate metacognition and knowledge', *Annals of Child Development,* 4, pp. 89-129.

Prestridge, S. (2019) 'Categorising teachers' use of social media for their professional learning: A self-generating professional learning paradigm', *Computers and Education,* 129, pp. 143-158.

Prestridge, S., and Main, K. (2018) 'Teachers as drivers of their professional learning through design teams, communities, and networks', in Voogt, J., Knezek, G., Christensen, R. and Lai, K.W. (eds.) *Second handbook of information technology in primary and secondary Education.* Springer International Handbooks of Education Series. Springer. https://doi.org/10.1007/978-3-319-53803-7_29-2

Quentin, I. and Bruillard, É. (2013) 'Explaining internal functioning of online teacher networks: between personal interest and depersonalized collective production, between the sandbox and the hive', *Society for Information Technology and Teacher Education, 24th Annual Conference SITE 2013,* New Orleans, USA, 25–29 March 2013.

Quentin, I. (2012) *Fonctionnements et trajectoires des réseaux en ligne d'enseignants.* Thèse de doctorat, ENS Cachan. https://tel.archives-ouvertes.fr/tel-00823180/document

Rabin, B.A., Glasgow, R.E., Kerner, J.F., Klump, M.P. and Brownson, R.C. (2010) 'Dissemination and implementation research on community-based cancer prevention: a systematic review', *American Journal of Preventive Medicine,* 38, pp. 443–456.

Ramírez, M.S. (2007) 'Administración de objetos de aprendizaje en educación a distancia: experiencia de colaboración interinstitucional', in Lozano, A. and Burgos, V. (Comps.), *Tecnología educativa: en un modelo educativo centrado en la persona.* México: LIMUSA, pp. 351-373.

Reich, J. (2012, June 25) *Battling over the meaning of "personalization"* [Online]. Available at: http://blogs.edweek.org/edweek/edtechresearcher/2012/06/battling_over_the_meaning_of_personalization.html

Reich, J. and Ito, M. (2017) *From good intentions to real outcomes: equity by design in learning technologies.* Irvine, California: Digital Media and Learning Research Hub.

Research in China (2017) *China Online Education Industry Report (2016-2021)* [Online]. Available at: http://www.researchinchina.com/UpLoads/ArticleFreePartPath/20170607171404.pdf

Ritter, S., Anderson, J.R., Koedinger, K.R. and Corbett, A. (2007) 'Cognitive tutor: applied research in mathematics education', *Psychonomic Bulletin and Review,* 14(2), pp. 249-255.

Rodríguez, J., Bruillard, É. and Horsley, M. (eds.) (2015) *Digital textbooks: what's new?* Santiago de Compostela: IARTEM. doi: 10.15304/op377.759

Roldán-Vera, E. (2001) 'Reading in questions and answers: the catechism as an educational genre in early independent Spanish America', *Book History* 4, pp. 17-48.

Rosé, C. P., McLaughlin, E.A., Liu, R., Koedinger, K.R. (2019) 'Explanatory learner models: why machine learning (alone) is not the answer', *British Journal of Educational Technology,* 50, 6, p. 2943-2958.

RTI International (2013). *Turkey's FATIH project: a plan to conquer the digital divide, or a technological leap of faith?* http://www.rti.org/sites/default/files/resources/fatih_report_eri-rti_dec13.pdf

Russell, T.L. (2001) The no significant difference phenomenon as reported in 355 research reports, summaries and papers: a comparative research annotated bibliography on technology for distance education. Chicago, Illinois: The International Distance Education Certification Center (IDECC).

Sammler, S. (2018) 'History of the school textbook', in Fuchs, E. and Bock, A. (eds.) *The Palgrave handbook of textbook studies*. Springer Nature, pp. 13-23.

Santana Bonilla, P.J., and Rodríguez Rodríguez, J. (2019) 'Does the use of educational digital resources at schools provide potentially new methodologies of teaching and learning? Some preliminary results from Digit@l School Research Project', in Bruillard, É., Anichini, A. and Baron G.L. (eds.) *Changing media – changing schools? IARTEM 2017, 14th International Conference on Research on Textbooks and Educational,* Lisbon, Portugal, 27-29 September 2017, pp. 10-15.

Scheirer, M. A. (2013) Linking sustainability research to intervention types. *American Journal of Public Health,* 103, e73–e80. doi: 10.2105/AJPH.2012.300976

Schleicher, A. (2018) 'Educating students for their future, not our past', *UNESCO MGIEP Blue Dot,* 7, pp. 7-10.

Schmid, U., Goertz, L., Behrens, J. (2017) Monitor Digitale Bildung. Die Schulen im digitalen Zeitalter. In https://www.bertelsmann-stiftung.de/fileadmin/files/BSt/Publikationen/GrauePublikationen/BSt_MDB3_Schulen_web.pdf <18.07.2019> Bertelsmann Stiftung (Hrsg.)

Scott, D. and Morrison, M. (2005) *Key ideas in educational research.* London and New York: Bloomsbury.

Seixas, P. (1999) 'Beyond content and pedagogy: in search of a way to talk about history education', *Journal of Curriculum Studies,* 31(3), pp. 317-337.

Shulman, L. (1986) 'Those who understand: knowledge growth in teaching', *Educational Researcher,* 15(2), pp. 4–14.

Shulman, L. (1987) 'Knowledge and teaching: foundations of the new reform', *Harvard Educational Review,* 57(1), pp. 1–22.

Siemens, G. (2005) 'Connectivism: a learning theory for the digital age', *International Journal of Instructional Technology and Distance Learning* 2(1), 3-10.

Singapore. 2018. *Smart Nation Strategy 2018* [Online]. Available at: https://www.smartnation.sg/docs/default-source/default-document-library/smart-nation-strategy_nov2018.pdf

Smart, A. and Jagannathan, S. (2018) *Textbook policies in Asia: development, publishing, printing, distribution, and future implications.* Manila: Asian Development Bank.

Snelling, J. (2018) Total turnaround: How LAUSD's troubled rollout became a model for tech success. *Empowered Learner, 1*(4), 19-23.

Stolurow, L.M. (1961) *Teaching by machine*. Cooperative Research Monograph no. 6. Washington, DC: US Department of Health, Education and Welfare. HathiTrust Digital Library [Online]. Available at: https://babel.hathitrust.org/cgi/pt?id=mdp.39015006508967;view=1up;seq=7

Tan, S.C. and Lee, A.V.Y. (2018) 'Online learning communities in K-12 settings', in Voogt, J., Knezek, G., Christensen, R. and Lai, K.W. (eds.) *Second handbook of information technology in primary and secondary Education.* Springer International Handbooks of Education Series. Springer. https://doi.org/10.1007/978-3-319-53803-7_48-2

The State Council of the People's Republic of China (2012) *Report on the work of the government.* Beijing, China: People's Publishing House.

Thorndike, E.L. (1912) *Education: A first book. New York*: Macmillan Co. Available at: https://ia601407.us.archive.org/16/items/educationafirst02thorgoog/educationafirst02thorgoog.pdf

Topping, K. J., Thurston, A., Tolmie, A., Christie, D., Murray, P. and Karagiannidou, E. (2011) 'Cooperative learning in science: intervention in the secondary school', *Research in Science and Technological Education,* 29, pp. 91–106.

UN (1992) 'Agenda 21', *United Nations Conference on Environment and Development,* Rio de Janerio, Brazil, 3-14 June 1992. https://sustainabledevelopment.un.org/content/documents/Agenda21.pdf

UN (2015) *Transforming our world: the 2030 Agenda for Sustainable Development.* A/RES/70/1. New York: United Nations. https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

UNESCO (2005a) *United Nations Decade of Education for Sustainable Development (2005-2014): International Implementation Scheme*. ED/DESD/2005/PI/01. Paris: UNESCO.

UNESCO (2005b) *Education for All: the quality imperative.* EFA Global Monitoring Report 2005. Paris : UNESCO.

UNESCO (2008a) *ICT Competency Framework for Teachers.* Paris: UNESCO.

UNESCO (2008b) *Education for All by 2015: will we make it?* EFA Global Monitoring Report 2008. Paris: UNESCO.

UNESCO (2011) *ICT Competency Framework for Teachers.* Paris: UNESCO.

UNESCO (2014a) *Roadmap for implementing the Global Action Programme on Education for Sustainable Development*. Paris: UNESCO.

UNESCO (2014b) 'Aichi-Nagoya Declaration on Education for Sustainable Development', *UNESCO World Conference on Education for Sustainable Development*, Aichi-Nagoya, Japan, 10-12 November 2014.

UNESCO (2015a) *Rethinking education: towards a global common good?* Paris: UNESCO.

UNESCO (2015b) *Global Citizenship Education: topics and learning objectives.* Paris: UNESCO.

UNESCO (2016) *Education 2030: Incheon Declaration and Framework for Action for the implementation of Sustainable Development Goal 4: ensure inclusive and equitable quality education and promote lifelong learning for all*. ED-2016/WS/28.

UNESCO (2017) *UNESCO moving forward the 2030 Agenda for Sustainable Development.* Paris: UNESCO.

UNESCO (2018a) *ICT Competency Framework for Teachers.* Paris: UNESCO.

UNESCO (2018b) *Designing Inclusive digital solutions and developing digital skills: guidelines*. Paris: UNESCO.

UNESCO (2019a) *SDG 4 - Education 2030: Part II, Education for Sustainable Development beyond 2019.* (206EX/6.II) Paris: UNESCO. https://unesdoc.unesco.org/ark:/48223/pf0000366797?posInSet=3and queryId=29c9bfa5-b7f1-4a7c-86ed-04144c0a5bae

UNESCO (2019b) *Artificial intelligence in education: challenges and opportunities for sustainable development.* Working Papers on Education Policy 7. Paris: UNESCO.

UNESCO (2019c) *Beijing consensus on artificial intelligence and education.* Outcome document of the International Conference on Artificial Intelligence and Education, 'Planning education in the AI era: lead the leap', Beijing, People's Republic of China, 16-18 May 2019. Paris: UNESCO.

UNESCO (2019d) *Artificial intelligence for sustainable development: synthesis report.* Mobile Learning Week 2019. Paris: UNESCO.

UNESCO Bangkok (2015) *Fostering digital citizenship through safe and responsible use of ICT: a review of current status in Asia and the Pacific as of December 2014.* Bangkok: APEID-ICT in Education, UNESCO Asia-Pacific Regional Bureau of Education.

UNESCO MGIEP (2017) *Rethinking schooling for the 21st Century: the state of education for peace, sustainable development and global citizenship in Asia*. New Delhi: UNESCO MGIEP.

UNESCO-UIS (2009) *Guide to measuring Information and Communication Technologies (ICT) in education.* Montreal: UNESCO Institute for Statistics. https://doi.org/10.15220/978-92-9189-078-1-en

UNESCO-UIS (2018) *Handbook on measuring equity in education*. Montreal: UNESCO Institute for Statistics. http://uis.unesco.org/sites/default/files/documents/handbook-measuring-equity-education-2018-en.pdf

Utah Education Network. (n.d.) *Educational Technology Endorsement Program (ETEP)* [Online]. Available at: https://www.uen.org/development/etep/

Utah State Board of Education. (n.d.) *Digital teaching and learning* [Online]. Available at: https://www.schools.utah.gov/curr/digital

VanLehn, K. (2011) 'The relative effectiveness of human tutoring, intelligent tutoring systems, and other tutoring systems', *Educational Psychologist,* 469(4), pp. 197-221.

Velázquez Sortino, M., Gómez-Zermeño, M. G. and Alemán de la Garza, L. (2017) 'Interactions in a Massive, Online, Open Course (MOOC) for teacher's: proposal for a model of analysis', *Digital Education Review,* 29, pp. 298-319.

Villani, C. (2018) *Donner un sens à l'intelligence artificielle : pour une stratégie nationale et européenne*. Rapport remis au Premier Ministre. https://www.aiforhumanity.fr/pdfs/9782111457089_Rapport_Villani_accessible.pdf

Vorvoreanu, M. (2014) 'Attention management as a fundamental aspect of 21st century technology literacy: A research agenda', 121st ASEE Annual Conference and Exposition, Paper ID #9256. https://pdfs.semanticscholar.org/fc08/f512b88679c32c1e49baf2531951c22c363c.pdf

Wals, A.E.J. (ed.) (2007) *Social learning* towards a *sustainable* world: principles, perspectives, praxis. Wageningen, The Netherlands: Wageningen Academic Publishers.

Wals, A. E. J., Brody, M., Dillon, J. and Stevenson, R. B. (2014) 'Convergence between science and environmental education', *Science,* 344 (6184), pp. 583-584.

Wilkens, H. J. (2011) 'Textbook approval systems and the Program for International Assessment (PISA) results: a preliminary analysis', *IARTEM e-Journal,* 4 (2), pp. 63-74.

World Bank (2017) *World Development Report 2018: learning to realize education's promise*. Washington, DC: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/28340/9781464810961_Ch07.pdf

Yankelovich N., Meyrowitz, N. and Van Dam, A. (1985) 'Reading and writing the electronic book', *Computer,* 18(10), pp. 15-30.

Zawacki-Richter, O., Marín, V., Bond M. and Gouverneur, F. (2019) 'Systematic review of research on artificial intelligence applications in higher education – where are the educators?', *International Journal of Educational Technology in Higher Education*, 16, Article number 39. doi:10.1186/s41239-019-0171-0

Zhang, E. (2017) *The Boss Interview - a gradual, evolutionary approach to disrupting education. Interview with 17zuoye Cofounder Dun Xiao* [Online]. Available at: https://medium.com/the-harbinger-china/a-gradual-evolutionary-approach-to-disrupting-education-b808285a1272

Zhu, Z. (2011) 'The e-school system and its function modeling', *E-education Research,* 4. Gansu, China: E-education Research Press.

17 Edtech Corporation (2019)一起教育科技品牌手册：全球知名的智能教育平台 *(17zuoye Brand Manual: Globally renowned intelligent education platform).* Shanghai: 17 Edtech Corporation.

36Kr (2018) 「一起作业完成*2.5*亿美元*E*轮融资, 公布主品牌一起」 (*17zuoye Raised $250 Million in a Series E Funding Round*) [Online]. Available at: https://36kr.com/p/5124735

Note: All UNESCO references can be easily found at UNESCO Digital Library at https://unesdoc.unesco.org/

Web links to images used in the Timelines (in chronological order)

Timeline 1

- Cai Lun (62-121A.D.) of Dong Han dynasty invented paper in 105 A.D.: https://in.pinterest.com/pin/3377768442415048/?lp=true
- Movable type printing technology (China): https://medium.com/@RossAlTejada/movable-type-the-very-first-printer-and-a-brief-look-at-its-history-4228bde57e9a
- Le codex Gigas: https://en.wikipedia.org/wiki/Codex_Gigas
- Oldest book printing with movable metal type Jikji (Korea): https://hi.wikipedia.org/wiki/%E0%A4%9A%E0%A4%BF%E0%A4%A4%E0%A5%8D%E0%A4%B0:Korean_book-Jikji-Selected_Teachings_of_Buddhist_Sages_and_Seon_Masters-1377.jpg
- Printing press (Gutenberg): www.pngfly.com/png-ql51k8/
- Gutenberg Bible: https://en.wikipedia.org/wiki/Gutenberg_Bible
- Gasparini pergamensis clarissimi oratoris epistolarum liber: https://www.themorgan.org/incunables/133638
- Magic lantern: https://en.wikipedia.org/wiki/Magic_lantern
- Semaphore telegraph: https://in.pinterest.com/pin/30399366213274245/?lp=true
- Industrial Printing Presses (newspaper printing machine): https://commons.wikimedia.org/wiki/File:Web-perfecting_newspaper_printing_machine.jpg
- Photography: https://en.wikipedia.org/wiki/History_of_photography (Photo above, retouched version of the earliest surviving camera photograph, 1826 or 1827, known as View from the Window at Le Gras; Photo below, View of the Boulevard du Temple, a daguerreotype made by Louis Daguerre in 1838)
- Electrical Telegraph: https://commons.wikimedia.org/wiki/File:PSM_V03_D423_Morse_telegraph.jpg
- Linotype: https://commons.wikimedia.org/wiki/File:Ottmar_Mergenthalers_linotypes%C3%A4ttmaskin.jpg
- Telephone: https://in.pinterest.com/pin/511932682612825199/?lp=true
- Cinematography: https://intheravine.wordpress.com/2014/08/31/history-of-cinema-edisons-kinetoscope-and-lumiere-bros-cinematograph/
- Television (Photo of John Logie Baird, who made the first transatlantic TV transmission, gave the first demonstration of colour TV and stereoscopic (3D) television and made the first video recordings): https://home.bt.com/tech-gadgets/tv/in-celebration-of-john-logie-baird-11363824455629

Timeline 2

- Pressey's teaching machine: https://slate.com/technology/2015/10/the-history-of-learning-machines-from-sidney-presser-and-b-f-skinner-to-mcgraw-hill.html
- Bush's MEMEX: http://483eclass.com/fall16/build_1/YooKyung/pages/Page03.html
- Skinner's teaching machine: https://en.wikipedia.org/wiki/Intelligent_tutoring_system
- Crowder's scrambled book (cover image): https://www.amazon.com/Arithmetic-Computers-Introduction-Binary-Mathematics/dp/B0006AWMPU
- Crowder's Autotutor, Mark II: https://www.researchgate.net/figure/An-Example-of-an-Intrinsic-Teaching-Machine-Copyright-John-Wiley-and-Sons-Inc_fig3_311858243
- Engelbart's NLS workstation: https://web.stanford.edu/dept/SUL/library/extra4/sloan/MouseSite/Archive/Post68/FinalReport1968/study68index.html
- Freinet's teaching box: https://www.etsy.com/in-en/listing/611642023/material-of-learning-from-the-1960s?show_sold_out_detail=1
- Nelson (diagram of the representation of hypertext): https://www.semanticscholar.org/paper/De-quelques-plantes-vertes-et-d%E2%80%99un-sch%C3%A9ma-cr%C3%A9ateur.-Crasson-Lebrave/0dc2460fe8b6d61f120699cd1642602c881d7796/figure/0
- Alan Kay's Dynabook: https://in.pinterest.com/pin/329326409974068 99/?autologin=true

With the exponential growth of digitally mediated communication, digital media and gaming, the landscape of what we understand as learning environments is changing significantly. Today the use of digital technology in education is attracting considerable public and policy attention as well as private investment. With a rise in discourses both heralding and cautioning against the use of digital technology in education, there is a need to pool the expertise and experience on the use of technology in education from around the world to advance public debate and evidence-informed policymaking.

Based on the literature review, mapping of digital education resources in circulation, and examples of implementation of digital education initiatives from around the world, this report aims to provide insights that would help lead to the wise, innovative and ethical use of digital technology in education as a new dimension in achieving SDG 4 — inclusive and equitable quality education and lifelong learning opportunities for all. By so doing, it also attempts to contribute to a rethink of teaching and learning in the face of enormous opportunities and challenges brought about by digital technology in the times of change and turmoil.

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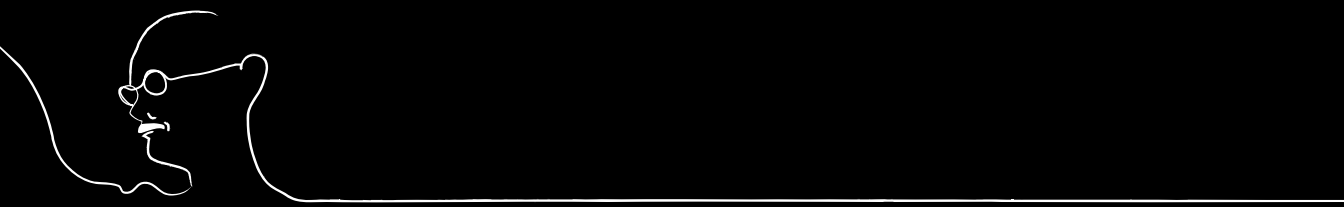

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