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ANALYTICAL REPORT

on the Use of Advanced ICT/AI for Digital Transformation of Education

Joint Report by the UNESCO Institute for Information Technologies in Education and Shanghai Open University

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Editorial Board

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Abbreviation and acronyms

AI	Artificial Intelligence
ICT	Information and Communications Technology
IoT	Internet of Things
LMS	Learning Management System
SOU	Shanghai Open University
TVET	Technical and Vocational Education and Training
UAE	The United Arab Emirates
UNESCO IITE	UNESCO Institute for Information Technologies in Education
VR/AR/MR	Virtual Reality / Augmented Reality / Mixed Reality
VLE	Virtual Learning Environment
OER	Open Educational Resources

Executive Summary

The development of digital technologies and their penetration into education opens up new opportunities for students, teachers, and educational organizations. Digital technologies make it possible to increase the accessibility of education as well as students' involvement in the educational process by enhancing their motivation and interest in learning, and by taking into account individual learning needs of both high-performing and low-performing students. In addition, use of digital technologies can significantly reduce the bureaucratic burden on teachers and increase the efficiency and transparency of organizational management processes. Effective implementation of digital tools requires for rethinking and redesigning various aspects of the activities of educational organizations and an integrated approach to digital transformation.

In recent years, there has been a high level of variance in the digital transformation processes across different organizations. This trend was especially pronounced during the first wave of the COVID-19 pandemic. Forced transition to remote work for teachers and students, who were unprepared to exist in the purely digital environment, exposed systemic deficiencies and barriers hindering the successful implementation of digital transformation in the education sector. At the same time, this forced transition contributed to the development and dissemination of new innovative practices using modern digital products based on advanced ICT.

In this context, it is extremely important to research the potential of digital technologies in education for their most effective application. A comprehensive analysis and systematization of digital opportunities are thus important to enhance the understanding of the current processes and trends in digital transformation of education and elaborate recommendations for teachers, heads of educational organizations, and policymakers in education.

The main purpose of this report is to analyze the cases of digital technology use collected within the framework of the project "Promoting ICT Capacity Building and Open Education in the Era of Artificial Intelligence and Digital Technologies" in the context of digital transformation of education. The project was initiated by the UNESCO Institute for Information Technologies in Education (UNESCO IITE) and Shanghai Open University (SOU).

The report comprises the following sections:

- An introduction that contains a description of the situation in the field of digital transformation of education and use of digital technologies in teaching and learning, as well as a substantiation of the relevance of the study and the conclusions obtained on its basis.
- Methodology defining the main approaches to the research and formulating the criteria for case analysis.
- Analysis of 36 cases of introducing digital technologies in education presented by educators from 11 countries.
- Conclusions summarizing the analysis of cases on the digital technologies used and recommendations for teachers, leaders of educational organizations, and policymakers in education.

Using the questionnaire (Annex 1), 36 practices from 11 countries (Armenia, Australia, Brazil, China, Croatia, India, Ireland, Russia, Serbia, United Arab Emirates, Zimbabwe) were collected between May and July 2021. An international panel of experts assessed each practice according to the following criteria:

- ◊ originality, innovativeness and transformative potential of the practice/initiative;
- ◊ reliability and scalability of the solutions developed/implemented;
- ◊ collaboration with partners and other stakeholders, engagement of teachers and students;
- ◊ aspects of digital transformation of education;
- ◊ advanced ICT used in the analyzed practice.

All practices were divided into three groups: national and international practices, practices of educational organizations, and practices of individual teachers. This systematization is based on the specifics of the tasks being solved, on various target audiences of the presented practices, and the differences in the principles of and approaches to implementing solutions.

The analysis of practices provided an opportunity to cover a wide range of issues related to digital transformation of education and to draw well-grounded conclusions about the priority areas of using digital technologies. It was shown that, along with the use of high-tech solutions for the transformation of education, initiatives related to solving the basic problems of digital transformations in the education sphere and the use of simple digital tools in teaching remain extremely relevant. The latter issue has become ever more pressing during the COVID-19 pandemic.

The collected cases cover all key areas of digital transformation of education, such as teaching and learning practices, organization of the educational process, content and curricula, assessment practices, professional development, and infrastructure. Many cases represent changes in teaching and learning practices, ranging from organizing training using the simplest digital tools to implementing personalized learning platforms. The important practices of involving students in the development of digital content and digital products, project-based training, and educational research are reflected as well.

The study highlights the importance of efficient organization of the educational process in a digital environment. The analyzed cases demonstrate various options for solving the problems of consolidating heterogeneous educational resources, managing distance learning, and more complex issues of adaptive management of educational trajectories and personalized selection of courses. Much attention is paid to developing and using digital educational content based on modern technologies, such as virtual and augmented reality, artificial intelligence, and the Internet of Things. The practice of using open digital educational resources and services as well as resources developed by other organizations and educators is important in the context of digital transformation.

Using digital technologies offers new opportunities for assessing students' knowledge and competencies. The analyzed cases present the practice of developing and using tools for assessing competencies based on the opportunities provided by digital platforms for collecting data and using specialized tools to automate complex assessment procedures that used to be carried out only by the teacher on the previous stage.

Professional development and the formation of teachers' digital competencies are essential for ensuring their technological readiness and increasing the efficiency of using digital technologies in education. Within our survey, several practices were identified that illustrate various approaches to organizing professional development.

Digital infrastructure development is no less important. It is necessary to note the changes in the requirements for organizations' infrastructure and physical environment associated with the need to create conditions for the effective use of solutions based on advanced ICT.

The survey also examined the role of advanced ICT in digital transformation of education. We identified digital technologies with the highest potential in the field of education as well as the main directions of their use.

On the basis of analysis, recommendations were prepared for teachers, heads of educational organizations, and policymakers in education. These recommendations cover the issues of integrating digital content into the educational process, planning and implementing digital transformation processes, organizing professional development, and modernizing infrastructure. Special attention is paid to the potential of digital technologies in education and the need to study best practices of their use and implementation, as well as to conduct research in the field of Edtech.

1. Introduction

Recent decades have seen a dramatic development of digital technologies penetrating all sectors of the economy and different spheres of public life. These technologies have been radically changing the logic of human interaction, the principles of organizing activities, imposing new requirements on professional competencies. Such changes known as "digital transformation" place new demands on the education system compelling it to adapt to the surrounding reality.

One of the main challenges of the digital economy is the pace of the emergence of new technologies and the obsolescence of the existing ones. In the modern world, individuals are forced to study every single moment, to master new knowledge and skills, and to abandon those already outdated. They have to manage their educational trajectories, which requires skills in self-organization, planning, and critical thinking. Communication skills, abilities to work in a team and collaborate to achieve project goals have become essential as well.

Digital technologies have been gradually replacing human labor in routine processes. As a result, some professions are under threat of extinction, while others await major changes. It has thus become very important to have a "creative core" in each profession. With the continuous growth in the volume and availability of information, the opportunities of global communication are also changing modern individual's expectations and needs.

However, while posing challenges to education, development of digital technologies also provides it with new opportunities. The analysis of modern trends in education (Dai, 2021; Holmes, 2018; Rivera, 2018; Roschelle, 2020; Sun, 2020; Tuomi, 2018) reveals digital technologies that have the greatest potential in digital transformation of education: artificial intelligence (AI), virtual reality (VR), augmented reality (AR), Internet of Things (IoT), big data, and blockchain.

Research shows that introduction of new digital tools using these technologies in the context of education development can allow to:

- ◊ increase the accessibility of education and provide learning opportunities for students who do not attend educational institutions temporarily or permanently;
- ◊ increase students' involvement and interest in the educational process;
- ◊ overcome the limitations of the traditional model of education by taking into account individual learning needs of students based on their abilities and results;
- ◊ effectively overcome various types of failure among students, identify problems, and propose ways to solve them;
- ◊ help students master specialized disciplines, try out future professions, and form primary professional skills;
- ◊ significantly reduce the bureaucratic burden on teachers;
- ◊ improve the efficiency and transparency of the organization's management processes and reduce decision-making time.

Digital transformation of education is a global trend for the modernization of educational systems and the transition to personalized forms of education, in contrast to traditional mass industrial forms. Digital technologies not only eliminate routine operations, such as keeping journals and diaries, but also force individual teachers and educational organizations to rethink their activities in order to define how they should be implemented and what should be changed, how to incorporate digital tools into educational practice and how it will influence the effectiveness of training, its goals, and content. This is a fundamental difference between digital transformation processes and the earlier processes of informatization of education, which we have witnessed in the past decades.

There is a high level of variance in how digital transformation processes are implemented across different organizations. Indeed, some innovative organizations actively introduce digital platforms and services, utilize modern digital content and promote digital literacy among teachers and students. However, in most educational organizations, digital transformation processes are not systemic and vary depending on the context.

This problem manifested itself especially clearly during the first wave of the COVID-19 pandemic when all stakeholders were trying to ensure the continuity of education. Difficulties experienced by teachers and students during this transition period revealed systemic deficiencies and barriers hindering digital transformation of education.

One of the key barriers, both at the level of organizations and individual teachers and students, was the digital divide. Many organizations lacked the necessary infrastructure and did not have financial resources to deploy digital platforms and services. The situation was further aggravated by the fact that distance learning required for special devices for educators and learners.

Another significant constraint was the low digital literacy level of teachers and schoolchildren. Lack of basic digital skills created major challenges in the transition to distance education. Moreover, lack of available teaching materials on the effective use of digital tools and efficient management of the educational process in a digital environment (digital didactics) exacerbated the decline in education quality for the majority of educational institutions.

Forced transition to distance learning caused by the COVID-19 pandemic has turned the spotlight on the digital transformation of education. Since then, we have been witnessing a positive shift in the level of digital literacy and technological readiness of teachers. Provision of basic digital infrastructure to educational organizations and the development of digital educational resources, platforms, and services are now critical to many development projects.

Under these conditions, it is necessary to explore the possibilities of digital technologies in education, develop a strategy for their effective use considering the speed of technological changes in the modern world and the need to nurture new competencies for students. Special attention should be paid to identifying, shaping, and promoting successful digital transformation practices at different levels.

Effective implementation of digital tools requires for rethinking and redesigning various aspects of the current activities of educational organizations. Educational researchers, governmental and international organizations, as well as private companies have developed several frameworks (e.g., Ferrari, 2013; Heymans, 2018; Ređep, 2018; Grajek, 2019) that determine the main directions of changes in educational organizations' activities in the process of digital transformation. All stakeholders of digital transformation should

not underestimate the importance of a systematic approach and should work in all key areas.

This report was prepared within the project "Promoting ICT Capacity Building and Open Education in the Era of Artificial Intelligence and Digital Technologies," implemented jointly by the UNESCO IITE and Shanghai Open University in 2021. The project's objective was to foster human and social development of UNESCO Member States using ICT-based innovative approaches with a particular focus on open education to expand access to relevant lifelong learning opportunities and enhance the quality of learning. The project's development and implementation were based on the idea that a comprehensive analysis and systematization of practices of digital technologies use are important for understanding the current processes and trends in the digital transformation of education and for elaborating recommendations for individual teachers, heads of educational organizations, and policymakers in education.

The report comprises the following sections:

- Methodology, defining the main approaches to the research and formulating the criteria for case analysis.
- Analysis of 36 cases of digital technologies in education presented by educators from 11 countries.
- Conclusions summarizing the analysis of cases on the technologies used and recommendations for teachers, leaders of educational organizations, and policymakers in education.

2. Methodology

This survey aims to analyze case studies that illustrate the use of advanced ICT in education and identify the aspects and areas of digital transformation of education that go beyond the practices presented in the submissions but reflect the use of advanced ICT/AI for digital transformation of education.

The desk research on the use of advanced ICT in education and frameworks for digital transformation of education made it possible to compare the structure and dynamics of digital transformation processes and reveal some aspects of advanced ICT, selected as additional criteria for evaluating the presented cases.

The following criteria were used while analyzing the cases:

- ◊ originality, innovativeness, and transformative potential of the practice/initiative;
- ◊ reliability and scalability of solutions developed/implemented;
- ◊ collaboration with partners and other stakeholders, and engagement of teachers and students.

In addition, the following areas and aspects of digital transformation were considered:

- ◊ aspects of digital transformation of education**:**
  - teaching and learning practices;
  - organization of the educational process;
  - content and curricula;
  - assessment practices;
  - professional development;
  - infrastructure.
- ◊ advanced ICT used in the analyzed practices.

Initially, the focus was on the following advanced ICT: artificial intelligence (AI), virtual reality (VR) and augmented reality (AR), Internet of Things (IoT), big data, and blockchain. Subsequently, though, some adjustments were made:

1. Artificial Intelligence and big data technologies were combined to form one type of advanced technology used by the respondents. In the context of this study, most examples of AI use were related to data analytics and big data.
2. A new category — "virtual simulators" — was introduced for software products that represent computer simulation of certain objects and processes without using VR and AR technologies.
3. The category "online communication" combines a set of technological solutions providing remote learning and interaction between teachers and students in virtual environments.

“Virtual simulators” and “online communications” were also considered advanced ICT due to a large number of cases describing the implementation of distance education during the COVID-19 pandemic.

3. Case Analysis

This section provides a short analysis of each of the cases studied. All cases were systematized according to the scope of practice — national and international, organizational, and individual. This systematization is underpinned by the specific goals and target audiences of the presented practices, and the differences in the principles and approaches to implementing solutions.

National and international practices are mainly aimed at solving global problems related to digital transformation of education. Organizational practices are focused on solving the issues relevant for organizations, depending on their level of digital maturity. Individual practices are designed to meet the needs of individual teachers.

This systematization is aimed to facilitate the replication of best practices among the relevant stakeholder groups.

3.1. National and international practices

This subsection outlines the initiatives implemented at the national and international levels. Their participants are various educational organizations or teachers and students from different organizations.

At this level, the main task is providing education systems with digital platforms and enhancing teachers' professional development. Most of the cases presented in this section can be subsumed within one of the following two groups:

- ◊ projects related to the development and use of digital platforms and ecosystems: projects 3.1.1 Moscow Electronic School, from Russia, 3.1.6 PM eVIDYA Program, from India, 3.1.7 Publicly Available Online Portal NASTAVA, from Croatia, 3.1.10 Visual-Cloud Classroom — Promoting the Quality and Fair Development of Lifelong Education, from China, and 3.2.14 Research on the Evaluation of Subject Education Quality under the Background of Big Data — A Case Study of Mathematics, from China;
- ◊ projects on the development of teachers' digital competencies: projects 3.1.2 Open Education Leadership Course, from Brazil, 3.1.5 HP Innovation and Digital Education Academy Program for the Middle East & Africa, from UAE, and 3.1.8 Online Repository of Educational Resources for Teachers, from Croatia.

There are also other practices not related to these areas but still worthy of attention — for example, developing communities of educators using virtual laboratories (3.1.3 Virtual Labs, from UAE) or a project to teach schoolchildren programming skills (3.1.4 Africa Code Week, from Zimbabwe).

3.1.1. Moscow Electronic School — MES; Moscow Department of Education (Russia)

Moscow electronic school is a digital educational resource for all teachers and schoolchildren of the city of Moscow.

Assignments for schoolchildren are uploaded into an electronic diary. Teachers check the work and grade it; sometimes they arrange surveys or control tasks. Students learn about

the schedule for the coming week through their electronic diary. Teachers set tasks and add descriptions to lessons, e.g., an online conference or an asynchronous lesson using the materials attached to the diary. The project is fully replicable elsewhere, as all online resources are publicly available and free.

3.1.2. Open Education Leadership Course; Open Education Initiative & UNESCO Brazil (Brazil)

The Open Education Leadership Course provides the collection of free and online courses for in-service and pre-service teachers, blending synchronous and asynchronous interaction modes. The objective is to create a network of educational leaders committed to educational transformation through the adoption of concepts and practices of openness and promotion of digital rights.

Remote and distance education tools used to communicate and to facilitate teaching and are Moodle, Discourse, Jitsi, and Big Blue Button. The promotion of free and open-source software (FLOSS) is included as well. While being country-specific, the Course can be adapted as a pedagogical tool to be used in various countries.

3.1.3. Virtual Labs; Ministry of Education (UAE)

This practice is aimed at increasing the use of virtual laboratories in educational research. The project team designed a comprehensive plan for advancing and using virtual labs through building teams, organizing meetings, workshops, and conducting lessons. Students and teachers present virtual experiments to the scientific committee to choose the best three. Different websites and applications are used to implement this solution. All the lessons and virtual experiments are available online.

3.1.4. Africa Code Week; SAP & UNESCO YouthMobile & Cape Town Science Centre & Galway Education Centre (Zimbabwe)

The global Africa Code Week is meant to empower the young generation by teaching the coding skills they need in order to succeed in the 21st century.

Using the PROFUTURO platform, teachers and learners are able to interact during the lesson despite being far apart. This system fosters youth curiosity, promotes creativity, and provides a basis for lifelong programming learning. The platform can also work in an offline mode allowing the young generation to learn how to code offline. Africa Code Week offers thousands of physical workshops that use Scratch for this particular age group to introduce them to coding.

This model provides a scalable structure for inter-group knowledge sharing. It unlocks people's potential and encourage them to share their experiences and resources with each other.

This practice is among those that promote the highest level of collaboration with other partners, and is highly innovative as it adapts the use of technology in education to the African context where such infrastructure is less readily available.

3.1.5. HP Innovation and Digital Education Academy (IDEA) Program for the Middle East & Africa; Ministry of Education (UAE)

The HP IDEA program for the Middle East & Africa aims to develop new methods of applying distance learning, increase student engagement, and support students through self-study methods.

HP IDEA promotes the development of effective teacher-leaders, embedding and scaling effective teaching skills across participating schools, and supporting innovation and entrepreneurship among teachers and students through:

- ◊ Developing a pool of effective online and blended learning teachers.
- ◊ Improving the quality and relevance of in-service teacher training.
- ◊ Supporting the growth of teacher-generated content.
- ◊ Improving workforce and employability skills.

This practice serves as a successful example of cooperation with the private sector; it is also operational in other contexts.

3.1.6. PM eVIDYA Program; NCERT & Ministry of Education (India)

The PM eVIDYA program is a comprehensive initiative which unifies all efforts related to digital/online/on-air education to enable multi-mode access to education. It will benefit nearly 250 million school-going children across the country. The initiative includes:

- ◊ DIKSHA (Digital Infrastructure for Knowledge Sharing) — national digital infrastructure for providing quality e-content for school education in states/UTs; and QR-coded Energized Textbooks for all grades (one nation one digital platform)
- ◊ One earmarked TV channel per class for grades 1 to 12 (one class one channel)
- ◊ Extensive use of radio, community radio, and the CBSE Podcast — Shiksha Vani
- ◊ Special e-content for visually and hearing impaired people developed on Digitally Accessible Information System (DAISY) and in sign language on the National Institute of Open Schooling (NIOS) website/YouTube.

DIKSHA is the 'one nation one digital platform' programme for school education on which 35 states and UTs have their own verticals along with those of the National Council for Education Research in Training, the Central Board of Secondary Education and NIOS of central government. DIKSHA can be accessed through a web-portal and a mobile application, and it consists of e-learning content for students of grades 1 to 12 in 32 Indian languages. It also contains modules for building teachers' capacity uploaded in different languages by state agencies.

The initiative is very complex, and education is provided in various ways not limited to online mode, as in many countries. This solution demonstrates high demand and reliability. During the period of the pandemic from April 2020 to June 2021 DIKSHA has seen over 22 million-page hits and over 600 million scans of QR e-content of textbooks.

This practice can be applied in other countries. It also serves as a good example of collaboration with various partners providing education through different channels.

3.1.7. Publicly Available Online Portal NASTAVA; ASOO (Croatia)

The publicly available portal https://nastava.asoo.hr/ hosts educational content developed by teachers and selected by experts. Using this portal, teachers can choose learning materials and issue assignments to their students.

Mentor teachers uploaded their materials to Google Drive, Dropbox, sent them through regular or file-transfer mail services to senior expert advisers for their sectors, who then reviewed and forwarded materials to expert associates for final editing. Finally, the content was published by expert associates on a WordPress portal.

A total of 6,336 educational articles were published for 13 educational sectors. This practice can be successfully used in other countries. It is an excellent example of fostering collaboration with various partners.

3.1.8. Online Repository of Educational Resources for Teachers; ASOO (Croatia)

The online repository of educational resources (https://edu.asoo.hr/#) provides different kinds of learning and teaching resources for TVET teachers to amplify their training and education. The portal presents 49 short-form written resources, five long-form written resources, 15 webinars, and four e-courses.

This practice is not particularly innovative. It lacks interactivity and serves just as a repository of available materials mostly presented in text format, with links to webinars.

Collecting resources from teachers and mentor teachers in TVET schools to be curated by senior expert advisers in their respective educational sectors contributes to the project's sustainability. This initiative has enabled the collaboration of different partners and managed to bypass the initial technical difficulties. There are no barriers to introducing this practice in other countries and regions.

3.1.9. Analysis of Digital Technology Use; Institute for Strategy of Education Development (Russia)

This case is a description of the results of a research focused on the experience of using augmented reality in foreign educational institutions, with due regard to possible negative consequences.

The author examines the potential of VR, AR and MR, which allow students to interact with virtual objects or to organize their participation in virtual processes for a more detailed and multidimensional perception of the objective reality, reflecting the studied subject area.

One of the key findings of the study is related to the negative consequences of the incorrect use of information and communication technologies in education affecting students' intellectual and moral development, reducing their level of physical health, and posing a threat to personal safety. Such research projects should be carried out more broadly to ensure that technology is used responsibly.

3.1.10. Visual-Cloud Classroom — Promoting the Quality and Fair Development of Lifelong Education; Shanghai Changning Spare-time University (China)

This platform is being developed by Shanghai Changning Spare-time University (Changning Community College). It represents a new lifelong education model that utilizes AI, cloud video, intelligent recommendation systems, big data analysis, cloud security, and voice recognition to connect teaching sites, communities of practice, and students online.

The platform is very easy to use: learners can access video and audio content, and engage in real-time interaction on any platform with only one click. The idea is innovative both in its use of technology and in the specificity of the context.

Among the strengths of this platform are the availability of a smart curriculum plan, intensive account matching, online cloud courses, accurate data visualization, and remote access to learning resources. The platform provides precise and personalized high-quality education services for learners as well as the possibility of choosing an individual trajectory of training, and promotes the quality of lifelong education.

The software offers a traditional template and is therefore stable and reliable. This helps it achieve coverage in all 16 of Shanghai's districts, and it is currently expanding its coverage to the remote areas of central and western China. To be scaled worldwide, this initiative should consider the issues of the ethical and legal norms and standards related to gathering personal data enacted in each particular country involved.

3.2. Practices of educational organizations

This section introduces practices implemented at the level of educational organizations. Some of the solutions presented can be implemented nationally or, conversely, by individual educators.

These cases are related to the creation of specialized platforms and tools that support the development processes of educational organizations and solutions to digital transformation problems. The innovativeness of the presented solutions depends on the level of digital maturity of each organization, from using simple LMS (3.2.3 Canvas LMS Use in the Georgian Institute of Public Affairs, Georgia) to developing a virtual simulation learning platform (3.2.8 Shanghai Information Technology College, from China).

This section is the largest in terms of the number of submitted innovative practices of using high-tech products in education. Due to their great complexity, they are much more difficult to scale up. This will require both the products' adaptation to the specifics of other organizations and a comprehensive transformation of these organizations' processes.

3.2.1. Online Platforms for Synchronous and Asynchronous Teaching; Chinhoyi University of Technology (CUT) (Zimbabwe)

Digital infrastructure is necessary for organizing distance learning during the COVID-19 pandemic. This solution demonstrates a coherent digital university environment developed using open software.

The CUT Student Success Program was integrated with the CUT Virtual Learning Environment using eLearning technical interoperability standards, thus capitalizing on application programming interfaces (APIs) and micro services. Training manuals were developed for both students and lecturers, followed by a series of training courses on

how to use new technology, the VLE, contemporary technology (cloud, Google Drive, Google Docs, online surveys, etc.), and how to deliver a live virtual lecture using locally hosted video conferencing services. This was followed by an upgrade of the university enrollment system (fully online operation: application, payment, registration, learning "via the VLE", providing information and feedback). Furthermore, efforts are underway to infuse machine learning techniques using online/digitally vigilant exam proctoring services (e.g., Safe Exam Browser).

Use of open-source technology makes such an initiative easier to scale up in various country contexts, especially in Africa.

3.2.2. TELMiE about IT; Marino Institute of Education (Ireland)

TELMiE about IT was focused on increasing the technological self-efficacy of staff and lecturers, so that they could deliver online by September 2020 in time for the new academic year.

MIE has been using models of technology integration to guide all technology projects, for both staff and students. The models provided a useful framework to outline how MIE could increase online learning provision. Using a "Train the Trainer" model, a Technology Enhanced Learning (TEL) champion was identified in each academic department. These champions in turn delivered training to others, acting as innovators and early adopters of the framework and ensuring their colleagues were fully trained to provide online and blended content for students. This provided staff with an opportunity for development in the technologies used during the training.

This practice is possibly the easiest to scale up, given its strategy of training the trainers. The idea of using several technologies at once is highly innovative and its cost-efficiency can ensure transferability across other countries.

3.2.3. Canvas LMS Use; Georgian Institute of Public Affairs (GIPA) (Georgia)

Using LMS, such as Canvas that organizes eLearning content in one location and provides unlimited access to eLearning materials, is the core idea of this case, presenting the practice of creating a useful virtual learning environment. This practice is widespread and not unique. Indeed, such tools are successfully used in many educational organizations.

3.2.4. Student Competency Monitoring Tool; Suhaila School for Basic Education (UAE)

Suhaila school developed and used a tool for tracking the formation and progress of students' skills in learning the Arabic language and mathematics. The tool created using Excel helps identify the skills required for learning per subject and student. This technology facilitates the follow-up process by monitoring progress and providing feedback to students and parents.

Although setting the time for training suitable for all teachers was quite a challenge, the school managed to get 94% of teachers to implement the initiative. The project is important as it helps monitor students' progress, whilst also being simple to replicate as it relies entirely on Excel. In this initiative, the teacher is the primary stakeholder. However, the tool also presents new opportunities for feedback to students and parents.

3.2.5. Smart Classroom Practice; Anting Elementary School (China)

The school provides a one-stop smart classroom learning environment for teachers and students with technical support in the form of a digital teaching platform and DingTalk Smart Classroom software.

Teachers use the platform to prepare their programming lessons. Each teacher can access a wide range of educational resources and learning analytics. Teachers interact with students through platform tools in the classroom, receives accurate learning feedback data when students complete their answers, and adjusts their teaching strategies accordingly. Students also use the platform to complete their homework. Teachers can then access the results of the completed homework and student notes.

Smart classroom practice has effectively changed teaching and learning methods. Moreover, the level of information literacy of teachers and students has been effectively enhanced, and students' independent and collaborative learning abilities have been strengthened.

Diversified simulations help students maintain positive learning attitudes and interest in learning, participate in learning activities autonomously and consciously, and constantly construct their knowledge to achieve self-adaptation and self-development. Despite the limitations associated with the use of specific platforms, this practice is scalable and high-potential.

3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph; Hangzhou Normal University (China)

This case describes the development of a cross-platform exploratory learning environment and assessment of the effectiveness of learning using this platform in comparison with traditional experimental learning.

Web3D technology uses 3D real-time distributed rendering technology to achieve real-time rendering of unlimited large-scale scenes. Multimodal learning behavior analysis technology is used to capture learners' behavior in real time and evaluate it through the built-in learning analysis model. A knowledge graph is used to describe the relevant concepts, entities, and events and their relationships with each other in the objective world. This platform presents a knowledge graph of each virtual experiment, including knowledge points, experimental instruments, and operational steps, so that learners can comb through the relevant concepts.

Using quasi-experimental research, questionnaires, and interviews, the teaching mode based on the Web3D virtual experiment is compared with a traditional experimental teaching mode. Thus the teaching effect of the exploratory virtual experiment is studied within empirical research, leading to the following conclusions: scientific experiments using the exploratory virtual environment have a moderate positive effect on the formation of knowledge and skills. It contributes to the improvement and cultivation of learners' interest, motivation, and scientific thinking.

This case is notable as its impact was measured and verified, making its potential seem more compelling than that of other practices. Still, the scalability of the project might come up against a number of technological barriers, namely the need for smartphones and other hardware devices for all end-users, the necessity of purchasing a server and

a cloud storage for a public/private organization. Also, the platform interface should be translated into other languages to allow for international use.

3.2.7. Intelligent Comprehensive Evaluation System; Shanghai High School (China)

The assessment system is implemented as a micro service platform and allows students to set their own learning goals, which are paired by learning tasks, activities, and social events automatically, and track the process of students' academic growth.

The system uses artificial intelligence and big data analysis technology to recommend personalized learning tasks for each student using specialized algorithms. Combined with teachers' comments for each student's curriculum and student data over the past ten years, the dynamic, intelligent recommendation system is utilized to reduce teachers' workload. Artificial intelligence, big data analysis, face recognition, voice interaction, and intelligent push notifications humanize students and teachers' interaction with the system.

The system seems relatively reliable and scalable from the technological perspective. However, gathering statistical and personal data should be aligned with the laws of the countries where the application may be used.

3.2.8. Virtual Simulation Learning Platform; Shanghai Information Technology College (China)

This solution provides an adaptive educational platform based on the use of virtual reality and artificial intelligence technologies. The platform implements personalized simulation training in a virtual environment.

The platform uses a wide range of technologies to improve learning efficiency: first, the use of virtual models and sensory simulations can significantly enrich students' experience, increase the efficiency of their learning, and provide them with access to modern quality digital content; IoT technologies enable collection of accurate learning data; and AI and big data technologies enable personalized learning and learning support.

According to the description of the system, it may be adopted to any educational context and, therefore, be used in an educational establishment of any type and at any educational level, which, in turn, contributes to its scalability.

This solution is targeted at different stakeholders: students and teachers, as well as parents and administrators.

3.2.9. Personalized Online Learning Support Service System; Shanghai Open University (China)

Personalized online learning support service system of SOU includes a full-learning-cycle comprehensive service, a personalized online learning service, a ubiquitous learning service with multi-terminal access, and support service mechanisms and teams.

The platform covers the entire study cycle, including teaching, learning, examination, administration, and support. Being AI-facilitated, it acquires learners' personal features, learning behavior, and learning style through the feature extraction technology to generate learning portraits. The platform also provides each learner with personalized

services such as remedial content notifications, learning alarms, and task notifications to improve knowledge acquisition.

The platform appears to be large and complex, but rather flexible, scalable, and reliable.

3.2.10. Smart Study Center; Shanghai Open University (China)

The Shanghai Open University (SOU) Smart Study Center has combined online and offline learning using integrated devices and technologies. This center aims to integrate a variety of pedagogies, environments, and technologies in one smart learning environment based on the characteristics of learners to produce flexible instructions that combine offline and online approaches to deliver optimal learning outcomes.

This case describes a unique practice of creating the physical infrastructure of an educational organization, which is necessary for effective use of advanced ICT in education. The educational space can adapt to different scenarios such as academic education, vocational training, and lifelong learning.

The Shared Services Center supports expository, collaborative, experiential, and flipped instruction using mobile learning, classroom interaction, IoT, table and chair arrangement, and smart instructional assistant. It blends virtual reality with mixed reality to deliver instructional experience that integrates in-person and remote students and thus offers remote individual learning. E-whiteboards can automatically save texts and send them to students' phones and support multi-terminal access. Smart teaching assistants help teachers by providing quick voice responses and controlling the devices in the space. Smart classrooms offer learners real-time interactive functions, including multi-screen interaction, pop quizzes, quick responses, discussions, feedback, resource sharing, and grouping. They also support concurrent online and offline participation.

Transforming learning environments is an important step towards successful digital transformation of education. The presented practice is of interest and can be fully or partially replicated by other organizations, while taking into account the cost of the solutions.

3.2.11. Accurate Teaching Efficient Learning — DigitalPen; Shanghai Yangjing-Juyuan Experimental School (China)

DigitalPen is a technological product that uses digital optical dot matrix technology to print a layer of invisible dot matrix patterns on ordinary paper. When students write, a high-speed camera on the front of the DigitalPen can capture the movement trajectory of the pen tip, while the pressure sensor transmits the pressure data back to the data processor and conveys information through Bluetooth or a USB cable transforming written texts into digital ones and collecting a wide scope of data associated with the exercises or learning tasks preformed.

After doing their homework, students receive instant feedback, allowing them to spend their time focusing purely on the questions they got wrong. The presented product is a balanced hardware and software solution, powered by AI; it has a curriculum transformative potential and demonstrates high efficiency as a teaching and learning tool. If there is a technical base, the presented practice is easily reproducible.

3.2.12. Shakespeare Drama Curriculum Group Project; Sisu Jiading Foreign Language Experimental School (China)

The Shakespeare Drama Curriculum Group implements cross-section, cross-disciplinary, and cross-curricular education, synthesizing the three in a way to reform teaching and learning processes.

Each grade has its own topic, e.g., the Animal Kingdom Opening Conference for the first grade. Curriculum development relies on “Shangxue Editor” software from Dolearning (SH) Education Science Co. The software supports rich media resources, including updated plug-in learning editors, a real-time learning assessment feedback system, and related interactive content. Eight digitized modules are used to support contextual experience simulation cases. These eight modules are video appreciation, story reading, animation creation, English practice, science learning, picture crafting, hand-made training, and drama performance.

By developing and implementing digital curriculum groups, students can experience contextual learning ambiance in accordance with real life, which could efficiently enhance their motivation for study. In addition, students can independently engage in eye-catching learning simulation tasks that involve interactions with contextual experience, and thus students' comprehensive abilities can be improved. What is more, introducing information technology provides practical, customized methods for students to conduct efficient personalized self-study. In this way, learning behavior data can be collected and applied in real time to integrate teaching, learning, and evaluation.

Students will experience interdisciplinary comprehensive practical activities involving Chinese, English, nature, art, ICT, and performance. By simulation cases, students could experience vivid interactive learning, ultimately enhancing students’ skills of reading, expression, artistic perception, creativity, teamwork and so on. Case simulation sets various learning requirements for each subject.

This practice appears to be very specific to this particular school and the drama classes it provides, meaning it may be challenging to replicate it in other contexts.

3.2.13. Use of Numerical Simulation and AI to Revitalize Physics Teaching in Junior High School; Shanghai Gold Education Software Co., Ltd & Shanghai Fengxian Education College Teaching Research Center & Shanghai Guhua Middle School (China)

The purpose of this project is to use numerical simulation and artificial intelligence technology to revitalize junior high school physics teaching. The software creates scenarios for students to learn empirically, enabling them to evolve via learning. The project was implemented by Shanghai Gold Education Software Co., Ltd., Shanghai Fengxian Education College Teaching Research Center, Shanghai Guhua Middle School, etc.

The project has solved the problem of creating scenarios for teachers by using simulation technology to create interactive scenarios and to achieve breakthroughs in learning difficult topics and in using exploratory teaching in daily practice.

It has also addressed the challenge of triggering students' learning motivation by using digital technologies to realize the "four actions in the classroom” (scenario interaction / problem triggering / data linkage / platform drive). The "four actions in the classroom"

approach made teaching more effective, thereby improving students' scientific thinking and ability to conduct scientific research.

The project has settled the conflict between test-oriented and essential skills-oriented education.

More than 30 public classes at all grades participated in this initiative to accelerate in-depth integration of IT and physics teaching and promote teachers' professional updating. Dozens of teachers took part in teaching evaluations and paper evaluations at all grades and achieved significant results.

This solution has demonstrated its scalability potential as the project was implemented in more than 500 schools and for more than 1,500 teachers in China. The software applied is of innovative nature, therefore, electronic devices should be provided and used in schools.

3.2.14. Research on the Evaluation of Subject Education Quality under the Background of Big Data — A Case Study of Mathematics; Shanghai Shidong Experimental School & Shanghai Xinyue Software Technology Co. (China)

This is a platform solution that facilitates the research and analysis of students' education. The "Thinking King" software system evaluates students, classes, grades, and schools based on data, and can predict development trends. It strengthens the evaluation of students' thinking process by recording, storing, visualizing and assessing it using step-by-step math problems on the computer.

The platform utilizes AI for comparative and developmental evaluation of students and classes, and provides teaching and learning guidance based on the results of such an evaluation. It also carries out further developmental evaluations of teaching abilities of school/college staff. The implementation of AI for performing assessments is innovative and has the potential to transform the method of knowledge evaluation.

The solution is still under development; the results of the experiment indicate the high potential of this solution and its methodology.

The project initiated and implemented by Shanghai Shidong Experimental School and Shanghai Xinyue Software Technology Co., involved teachers from different schools.

3.3. Practices of individual teachers

This section presents cases describing the practices of individual teachers related to the use of digital tools in the educational process and organization of their activities in digital environments.

Most of the practices presented are designed to increase student engagement and enrich the educational process through simple digital tools such as interactive presentations (3.3.1 Interactive PowerPoint Presentations Played by Students on Android Phones and Smart Boards, from Serbia) or websites (3.3.10 Using the National Geographic Website in a Biology Class, from UAE).

At the same time, several initiatives focus on the formation of students' digital competencies (3.3.6 Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers, from Serbia) or the development of software products by students

(3.3.11 Software Development to Improve Human Immunity System by Regulating Food Intake — Al Madam Girls School, from UAE).

These practices can be easily and successfully scaled up, and do not require institutional transformations in educational organizations.

3.3.1. Interactive PowerPoint Presentations Played by Students on Android Phones and Smart Boards; anonymous elementary school teacher (Serbia)

Using interactive PowerPoint presentations and interactive games, which can be played on Android phones and smart boards, encourages students to engage in different areas of their education (school subjects). This is a simple and appealing solution that can be scaled up widely.

3.3.2. Belgrade Adventure Project; Ms. Lidija Zupanic Suica, President of the Association "Education for the 21st Century" (Serbia)

This project aims to equip high school students with lifelong learning skills and promote democratic culture by developing a website (and soon an app for the Google Play Market) with 40 cultural sites, focusing on cultural heritage of Serbian cities (looking at buildings and each area's heritage).

The project was inspired by curricula for arts subjects (these include not only applied arts, but also history of art and cultural heritage). Students are divided into groups, each group examines a cultural or historical site. The division of tasks implies having a group coordinator responsible for managing, planning, and completing envisioned tasks directed at the digitalization of content (images, texts, design). Mentors provide group visits, offer literature for research, and liaise students with local institutions.

This idea is original in the sense that it adapts to the national context, but its specificity means it may not be adapted to other country contexts.

3.3.3. OpenEssayist; Ms. Denise Whitelock, Open and Oxford Universities (Australia)

This section looks at the practice of using OpenEssayist, a real-time learning analytics tool, based on Natural Language Processing software and a web application to provide automated feedback to students on their draft essays before submitting them for formal assessment.

OpenEssayist uses Natural Language Processing, linguistic technologies, graphics, animations, and interactive exercises to enable students to reflect on whether their essays adequately convey their ideas and to self-correct their essays before submitting for summative assessment. OpenEssayist processes the texts of student essays and offers feedback through key phrase extraction and extractive summarization. Each essay is automatically preprocessed using modules from the Natural Language Processing Toolkit, which includes several tokenizers, a lemmatizer, a part-of-speech tagger, and a list of stop words. Key phrase extraction identifies the phrases that are most suggestive of the content, and extractive summarization identifies key sentences. These constitute the basis for providing feedback.

OpenEssayist is an online tool that students can access and use from any location, which is particularly helpful in the context of distance learning.

OpenEssayist was developed by a team of researchers from the Open and Oxford Universities and piloted and used with students at the Open University, Hertfordshire University in the UK, and Dubai University.

3.3.4. Drobik Chatbot; Ms. Tatyana Tebenkova, General School of Kemerovo (Russia)

This initiative was designed to create chatbots for students to learn mathematics. After studying a math topic, students communicate with the chatbot to gain a better understanding.

Introducing this chatbot has increased students' interest in learning mathematics and developed a superior understanding of the subject. Communication with the bot is convenient for those students who feel too embarrassed to ask teachers for clarifications.

Such an initiative seems to be very popular and to complement rather than replace face-to-face teaching, which makes it easy to scale up.

3.3.5. Project "COVID-19: Equal Right to Education"; Ms. Meri Grigoryan, UNESCO Chair on Education for Sustainable Development of the Center for Ecological Noosphere Studies (Armenia)

This project involves conducting educational research on the advantages and disadvantages of distance learning. The participants were students engaged in distance and hybrid formats of learning.

The research revealed that, despite some learning difficulties experienced during the COVID-19 pandemic, application of ICT in the educational process enabled students to use innovative educational and research resources, revitalized learning methods, established more active collaboration between students and teachers and contributed to acquiring new technological knowledge.

The practice of organizing such a research can be successfully replicated. The project was carried out in UNESCO Associated Schools and in partner schools of Yerevan and Ufa to examine the quality of education during the COVID-19 pandemic.

3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (DIGinGEOteach); Ms. Anđelija Ivkov Džigurski & Ms. Ljubica Ivanović Bibić & Ms. Smiljana Đukičin Vucković & Ms. Jelena Milanković Jovanov (Serbia)

This project is focused on teaching geography, and its main goals are: improving digital competencies of students and future teachers, enabling students to organize a field classroom and apply modern techniques; educating teachers to instruct students in the use of scientific research methods and work on projects to acquire new content in the field of geography. With the help of digital applications, in addition to keeping digital school diaries, teachers can keep records, organize classes and lectures, and store work and supplementary material for students and parents in one place.

A database of useful teaching materials was created (using Microsoft Teams) to facilitate teachers' preparation for classes, including PowerPoint presentations to process the materials, online tests and questionnaires to evaluate knowledge, QR codes for teaching, and videos for distance teaching. Based on the given examples, students/future teachers can create similar materials for other teaching topics.

During their classes, teachers applied the most useful tools for online teaching and got acquainted with the possibilities of applying VR in teaching using VR glasses.

Although this practice is geography-oriented, it has potential for replication in other subjects.

3.3.7. Video Stories for Children with Disabilities and 3D Animations Using Artificial Intelligence; Mr. Petar Alfirević & Ms. Magda Maver, Graditeljsko Geodetska Tehnička Škola Split (Croatia)

For this practice, video materials about Diocletian's Palace in Split, Croatia, were developed for children with special needs.

These materials present the way of life in the past through UNESCO World heritage sites. The main benefits they deliver can be seen through innovations in producing learning content, developing intercultural competences of students through the promotion of cultural diversity as a common value, displaying various types of intercultural and creative 3D animations, fostering creativity using AI, and developing artistic visual expression and practical knowledge and skills.

The video material has no potential for replication, but the proposed approach can be used in other countries. Moreover, these videos can be used not only for children with special needs.

3.3.8. Critical Thinking Teaching about Media Content; Ms. Violeta Kecman, Higher School of Communications and Fifth Belgrade High School (Serbia)

This is a new methodological approach. It does not directly focus on teaching specific subjects but rather on providing training on the use of technology. The idea is to teach students to reflect upon their knowledge of how search engines, aggregators, and social networks are used to deconstruct media content, pseudo-scientific information, and fake news.

Although most high school students assume that they know how to interact with search engines and content aggregators, they still lack a clear insight into how the results of their search depend on their behavior online. It is therefore necessary to raise students' awareness of the fact that their search results can be influenced by various commercial and/or political interests, as well as by algorithms that rely on behavioral patterns in the digital environment.

This project is unique and has an impact on different countries.

3.3.9. Teaching Programming Using Specialized Digital Educational Resources; teachers and students (country not indicated)

This initiative presents an approach to organizing the educational process using external digital educational resources, such as Code.org (https://code.org/), Hour of code (https://hourofcode.com/), and MIT App Invertor (https://appinventor.mit.edu/).

Various websites propose flipped/blended classrooms where students start at a given level of coding and then move up the scale. Such websites enhance the accessibility of education to make it readily available and easier to understand for all students. These

sites often use AI-based technologies, which aim to contribute to improving the learning process and developing new methods of teaching.

The technological aspect of this submission is highly robust and innovative. It can also be easily replicated across various countries with access to such complex tools.

3.3.10. Using the National Geographic Website in a Biology Class; Ms. Shaimaa Alyammahi, Merbah Secondary School (UAE)

In biology lessons, students were encouraged to study the content of the National Geographic website. More specifically, their task was to choose an article regarding any topic in biology and summarize the article in four or more points.

Such an activity enhanced students reading skills and increased their awareness of international biological and environmental issues. Also, students learned more about the Sustainable Development Goals and the ways of achieving them. Using online reading thus helped the students to improve their fast reading skills and enabled them to obtain knowledge about the world and its cultures, developing their sense of tolerance.

This practice is not innovative in terms of the use of advanced ICT. However, due to the simplicity and availability of information resources, it is freely scalable.

3.3.11. Software Development to Improve Human Immunity System by Regulating Food Intake; students, Al Madam Girls School (UAE)

This initiative is designed to develop software to improve the human immune system by regulating nutrition intake. The application monitors how much nutritious food an individual eats on a daily basis and notifies about any deficiencies. It also generates a comparison of users' overall nutrition intake and progress. Participants are students of Grade 9 advanced, Grade 10 advanced, and Grade 10 general classes.

The application was effective at tracking the nutritional value of some common foods worldwide and, more specifically, Arabic meals and their vitamins and minerals.

Also, project participants benefited by learning more about the Python programming language, which is a part of their curriculum, thereby increasing the motivation for learning, acquiring knowledge, and developing skills.

The project is of significant value and can be scaled up successfully in other organizations and countries.

3.3.12. Half-Day Inspection Course "Walking into the Humanistic Sites of Tianping Road and Hunan Road"; Gao'an Road Primary School (China)

This initiative is a website that children can visit in order to take part in treasure hunts in simulated celebrities' homes.

The solution is innovative in its decision to gamify the process of online learning in the form of a cultural quest. It is not clear from the description, but it might be powered by weak AI as it traces the behavior of users and modifies the game plan. The subject area of the app's educational content contemplates the study of the same unique Chinese cultural and historical artefacts that seem interesting and may foster its spread and scaling up in Chinese high schools and international schools specializing in Chinese culture studies.

The app itself was designed with conventional software that contributes to its stable, reliable usage and scalability. The practice seems extremely challenging to replicate in other contexts as it is very specific to this particular high school and to the niche interest of exploring celebrities' houses.

3.4. Results

While analyzing the cases, several significant aspects of using digital technologies in different contexts of digital transformation of education were identified.

Digital maturity

Although there are many examples of the use of high-tech solutions in education among the presented practices, most of the initiatives aim to solve the basic problems of digital transformation and use simple digital tools in education.

This effectively illustrates both the problems and necessary solutions that educational organizations and educators had to consider in view of the COVID-19 pandemic as well as the new trends in digital transformation that have emerged during this period. These are closely associated with a large number of teachers having to engage with digital solutions for the first time.

Among the above-mentioned practices, there are national initiatives aimed at the formation of digital content repositories that teachers can use in their activities (cases 3.1.1 Moscow Electronic School, from Russia, 3.1.7 Publicly Available Online Portal NASTAVA, from Croatia), national and international initiatives for the development of teachers' digital competencies (3.1.8 Online Repository of Educational Resources for Teachers, from Croatia, 3.1.5 HP Innovation and Digital Education Academy Program for the Middle East & Africa, from UAE, 3.1.2 Open Education Leadership Course, from Brazil), and the use of basic tools for organizing the educational process in digital environments (3.2.1 Online Platforms for Synchronous and Asynchronous Teaching by Chinhoyi University of Technology, from Zimbabwe, 3.2.6 Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph — Hangzhou Normal University, from China).

A separate group worthy of special attention includes the initiatives of individual teachers to use digital tools in the educational process, such as interactive presentations (3.3.1 Interactive PowerPoint Presentations Played by Students on Android Phones and Smart Boards, from Serbia), chatbots (3.3.4 Drobik Chatbot, from Russia), and even systems for semantic text analysis (3.3.3 OpenEssayist, from Australia). These have a low threshold of entry, do not require advanced teacher competencies and profound transformations of the educational process, and allow educators to quickly enrich the educational process, thus increasing student engagement and improving educational results.

In this context, navigators of publicly available digital tools and educational platforms for use in the educational process should be noted, such as those created by Holmes (2018) and Karlov (2020), which are important tools to support teachers and educational organizations.

Areas of digital transformation

Effective use of digital technologies requires an integrated approach to digital transformation. Among the cases presented, there are practices related to all key areas of digital transformation.

Teaching and learning practices

Changes in teaching and learning methods are associated with the immersion of digital tools in the educational process. One of the priority issues on the agenda of digital transformation of education is actively represented by various initiatives within the framework of this study. 23 out of 36 cases are related to new learning and teaching practices in the digital environment. The cases cover various practices, ranging from organizing training using the simplest digital tools described above to personalized learning platforms.

Personalization of learning is the most important trend in digital transformation of education (Holmes, 2018). Modern solutions based on AI technology make it possible to implement adaptive learning, ensuring the selection of educational content and assignments that are adapted to students' characteristics and needs. The cases studied include interesting practices of supporting online learning at Shanghai Open University (3.2.9 Personalized Online Learning Support Service System of Shanghai Open University, from China) and adaptive educational platforms in educational organizations (3.2.5 Smart Classroom Practice in Anting Elementary School, from China, 3.2.6 Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph — Hangzhou Normal University from China, 3.2.8 Virtual Simulation Learning Platform — Shanghai Information Technology College, from China, 3.2.11 Accurate Teaching Efficient Learning — DigitalPen, from China).

An important direction is engaging students in the development of digital content and digital products. This is well illustrated by the cases of the landmarks of Belgrade in the Belgrade Adventure Project (3.3.2 Belgrade Adventure Project, from Serbia) and the Regulating Food Intake application (3.3.11 Software Development to Improve Human Immunity System by Regulating Food Intake — Al Madam Girls School, from UAE).

Another area of change in educational practices is associated with project-based learning and educational research. This direction is represented by the description of the study “COVID-19: Equal Right to Education” (3.3.5, from Armenia) and the practice of using virtual laboratories for research in schools (3.1.3 Virtual Labs, from UAE).

Organization of the educational process

Transition to distance learning during the COVID-19 pandemic highlighted the problem of effective organization of education in the digital environment. Using various digital platforms and tools within the same class required for the availability of learning management systems. Organizations that did not have access to such systems faced serious problems related to the interaction between teachers and students.

The use of learning management systems (LMS) made it possible to consolidate diverse educational resources, manage the schedule of synchronous online classes, and assign and monitor homework. Among the analyzed practices, there are many examples of using digital platforms for organizing the educational process, ranging from classic LMS (3.2.3 Canvas LMS Use in the Georgian Institute of Public Affairs, from Georgia, 3.2.1 Online Platforms for Synchronous and Asynchronous Teaching by Chinhoyi University of

Technology, from Zimbabwe) to more complex platforms that provide personalized content selection, particularly the case of the Visual-Cloud Classroom project (3.1.10 Visual-Cloud Classroom — Promoting the Quality and Fair Development of Lifelong Education, from China).

An important aspect of the educational process is the ability of students and their parents to track learning progress. For example, the Student Competency Monitoring Tool project (3.2.4 Student Competency Monitoring Tool — Suhaila School for Basic Education, from UAE) uses a simple Excel spreadsheet tool that allows students to track their progress in the classroom.

Content and curricula

Digital technologies present new opportunities to design educational content. The use of VR/AR technologies enables the creation of digital content that ensures higher involvement of students. Learners can build and practice their primary skills in working with complex or even dangerous systems. Thus, within the framework of the project 3.2.13 Use of Numerical Simulation and Artificial Intelligence to Revitalize Physics Teaching in Junior High School, from China, more than 200 scenarios of interactive simulation in physics lessons have been developed, and in Shanghai Information Technology College (3.2.8 Virtual Simulation Learning Platform, from China) a holistic educational environment allows to organize training with virtual simulations.

In the context of digital transformation, much attention is paid to the use of open educational resources and services for teachers and by teachers or by educational organizations. Projects 3.1.7 Publicly Available Online Portal NASTAVA, from Croatia, and 3.1.1 Moscow Electronic School, from Russia, promote interesting experiences of providing tools and organizational mechanisms for posting teacher-developed digital content and using it in class.

Educational resources for teaching programming (3.3.9 Teaching Programming Using Specialized Digital Educational Resources) and the use of the National Geographic website in biology lessons (3.3.10 Using the National Geographic Website in a Biology Class, from UAE) are great examples of working with external content.

Assessment practices

The use of digital technologies presents new opportunities for assessing students' knowledge and competencies. In AI and the Future of Learning: Expert Panel Report (Roschelle, 2020), the authors identify transforming assessment as one of two key uses of AI in education.

The main direction of assessment practices development is the analysis of data from digital platforms. Artificial intelligence and big data enable data-driven evaluation of competencies using digital data on user actions in digital environments. For example, Shanghai High School (3.2.7 Shanghai High School Intelligent Comprehensive Evaluation System, from China) has created a comprehensive assessment system that allows students to set learning goals and track their progress independently. An example of a comprehensive solution that includes modern assessment tools is the Personalized Online Learning Support Service System of Shanghai Open University (3.2.9, from China).

The use of digital technologies for developing new assessment tools is of great potential in education. Artificial intelligence as well as virtual and augmented reality methods make it possible to develop tools that automate complex assessment procedures. The

practice of using Natural Language Processing algorithms for evaluating students' essays (3.3.3 OpenEssayist, from Australia) is a case in point.

Professional development

Teacher training and professional development, including the formation of their digital competencies, are important to ensure their readiness for a constantly changing work environment and their ability to use digital technologies efficiently for educational purposes. In this process, it is important to enrich individual practices with different approaches that have already proven their effectiveness.

National and international educational programs, such as "Open Education Leadership course" (3.1.2 Open Education Leadership Course, from Brazil) and "HP Innovation and Digital Education Academy" (3.1.5 HP Innovation and Digital Education Academy Program for the Middle East & Africa, from UAE) contribute to the development of teachers' digital competencies.

With the emergence of digital technologies and new tools, horizontal learning has become increasingly important. The TELMiE about IT project (3.2.2 TELMiE about IT, Marino Institute of Education, from Ireland) is an example of an effective organization of such learning.

Platforms with online courses and materials for educators are being developed to provide opportunities for their self-education. A case in point is the project "Online Repository of Educational Resources for Teachers" (3.1.8, from Croatia).

Complex projects for pre-service teacher training on how to use digital tools in class are of particular interest. Within the DIGinGEOteach project (3.3.6 Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers, from Serbia), future teachers master digital tools and develop scenarios for using digital products in geography classes.

Infrastructure

Lack of digital infrastructure in educational institutions is the most important deterrent to digital transformation and effective use of digital technologies. The analysis of the presented cases demonstrates a wide variety of ways to provide digital infrastructure in different organizations, both within individual countries and between countries and regions.

However, changes in teaching and learning practices associated with introducing new technologies impose more complicated requirements for educational organizations and their infrastructure. The case of Shanghai Open University presents the experience of creating a Smart Study Center (3.2.10 Smart Study Center of Shanghai Open University, from China). The authors of the project managed to combine online and face-to-face training opportunities in their organization and to create conditions for effective use of digital technologies. Studying such examples is necessary when designing new environments and developing new projects providing educational institutions with digital infrastructure.

4. Conclusion

The initiatives analyzed in this report focus on various aspects of digital transformation of education. For each initiative attention is paid to the area of digital transformation, technologies used, levels of implementation of practices, and the maturity of the presented solutions. It provides a broad picture of digital technologies in education and allows readers to make informed conclusions about priority areas of change.

Most of the reviewed practices are based on simple digital tools and do not use advanced ICT. However, the main driver of education development is integrating advanced ICT-based tools into the educational process. Understanding the potential of technologies and analyzing their use in other industries provide for creating new revolutionary educational products that can improve the quality of education and solve the existing problems.

The results of this analysis allow to identify several technologies with the highest potential when applied to education.

Artificial intelligence

This is the most promising digital technology in education. AI-based solutions have been actively developed and implemented at all levels of education.

The main areas of AI technologies use are:

- adaptive learning platforms;
- recommendation systems for students and teachers based on big data;
- specialized educational tools based on Natural Language Processing, Computer Vision, and other fields.

In 15 out of 36 practices, we see different uses of AI technology in education.

Furthermore, an important area of using AI, which is not reflected in the analyzed cases, is automated translation. In several developing countries, the language of instruction is not the same as the children's mother tongue. As a result, teachers often deliver classes in languages that students have not mastered. By using translation tools, teachers can ensure accessibility.

Virtual Reality and Augmented Reality

VR/AR technologies can significantly enrich the educational process by visualizing and completing elements of a lesson, acting as a constructor tool and material for creativity, as well as enabling in-depth knowledge of physical and chemical processes (Al Kork, 2018; Ochoa, 2018; Sun, 2020).

Such technologies make the educational process vivid and interactive, increasing students' involvement and thereby positively impacting their academic results.

Virtual reality models allow trainees to develop certain skills safely and without fear of failure, while acquiring these skills under real-life conditions would be associated with hazards or constraints, such as the availability of equipment, high cost of work, and the risk of exposing other people to danger.

Internet of Things

IoT is the concept of a computing network of physical objects equipped with built-in technologies to interact with each other or with the external environment. It enables the integration of physical learning objects, such as STEM constructors, into the digital environment to provide feedback to students on the results of their work and to collect and analyze data.

The use of IoT is becoming increasingly widespread in education. However, the potential of this technology in the educational sphere has not yet been fully explored.

The DigitalPen project (3.2.11 Accurate Teaching Efficient Learning — DigitalPen by Shanghai Yangjing-Juyuan Experimental School, from China) describes the experience of using pens in teaching, recognizing the text written by the student, and providing a rapid check of the tasks being performed.

The projects "Virtual simulation learning platform" (3.2.8 Virtual Simulation Learning Platform — Shanghai Information Technology College, from China) and "Smart Study Center" (3.2.10 Smart Study Center of Shanghai Open University, from China) outline the practices of integrating IoT devices into the digital educational environment.

Another important area of using digital technologies in education, which practically did not fall within the focus of the analyzed projects, is training people with special educational needs (the only example is “Video stories for children with disabilities and 3D animations using artificial intelligence”, from Croatia). Digital technologies make education accessible to students who are unable to attend educational institutions, and the use of modern solutions based on advanced ICT significantly increases the potential for equity and inclusion.

Drawing on the analysis of the cases, it is possible to elaborate some recommendations for teachers, educational leaders, and policymakers:

1. Educational organizations and individual teachers should use open educational resources and publicly available services in educational activities. Open tools allow educators to provide good results with minimal time and financial costs.
2. It is advisable to re-use digital content developed by other educators and educational organizations. The actions of policymakers should be aimed at creating conditions for the development, storage, distribution, and use of OER.
3. Educational leaders and policymakers need to create conditions to ensure equal access of students to digital content, using the capabilities of advanced ICT to contribute to bridging the digital divide.
4. When developing a strategy to modernize education, educational leaders and policymakers must consider the complexity of digital transformation processes. It is very important to cover all key areas of change to ensure the effective use of digital technologies.
5. There are no universal solutions to cover all aspects of digital transformation with maximum effect, and focusing on successful practices (including those presented in this report) will help define a set of solutions that, to a certain extent, satisfies the needs of a particular student, teacher, or educational organization.

6. Special attention should be paid to equity and inclusion. It is necessary to take into account the interests and needs of different stakeholders in education.
7. Most of the practices focus on providing opportunities for learners and educators. However, parents, administrators and policymakers can greatly benefit from the same tools.
8. It is necessary to support various approaches to organize professional development. Educators are encouraged to use available OER for self-development. A system of professional development, including horizontal learning tools, is to be designed.
9. When implementing programs aimed at the development of digital infrastructure, it is recommended to consider new requirements for an enabling educational environment that may help ensure the effective use of digital tools.
10. A systematic, repetitive, and recursive analysis of various digital technologies' potential and new possibilities in education is necessary. For this, educational organizations and individual teachers are encouraged to regularly experiment with various tools and resources to assess their capabilities. Moreover, conditions for such experiments and support for the spread of successful practices are to be ensured.
11. In most projects, technology is considered de facto useful for education. However, its use should be scientifically grounded and aimed at the improvement of learning outcomes, increase in the efficiency and effectiveness of teachers' work, as well as in the transparency of educational organizations. In order to do this, policymakers should support evaluation and validation studies.
12. Piloting and working with feedback is also very important. By piloting and evaluating an approach in specific contexts, its generalizability to a larger audience can be estimated based on participants' input. It is cost-effective and ensures participation of a wider group of stakeholders in the decision-making process.

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Annex 1. Call for Submissions on Collecting Innovative Practices on Digital Transformations Related to Use of Advanced ICT and AI in Education

United Nations Educational, Scientific and Cultural Organization

UNESCO Institute for Information Technologies in Education

SHANGHAI OPEN UNIVERSITY

CALL FOR SUBMISSIONS

Collecting Innovative Practices on Digital Transformations Related to Use of Advanced ICT and AI in Education

UNESCO Institute for Information Technologies in Education (UNESCO IITE) and Shanghai Open University (SOU) open a call to share best practices on digital transformations related to use of advanced ICT in education, including artificial intelligence (AI).

The best practices are collected within the UNESCO IITE/SOU joint project on "Promoting ICT Capacity Building and Open Education in the Era of Artificial Intelligence and Digital Technologies". The overall purpose of this initiative is to foster human and social development of UNESCO Member States through the use of ICT-based innovative approaches with a particular focus on open education to expand access to relevant lifelong learning opportunities and enhance the quality of learning. The collection of best practices aims to improve understanding of the potential, benefits and limitations of AI and advanced IT among educators. It is expected that innovative practices include new ways of working and transformative "out-of-the-box" thinking and actions, including the themes covered, the methodology employed and possible channels used to create change in education. Practices collected will be used to develop an analytical review to be widely distributed.

To take part in the Initiative and to share your innovative experience in using advanced ICT in education, please fill in the form or send the description of your practice to the email. The description should include the following information:

1. Indicate the area or areas of innovation:
    a. Enhancing of education accessibility and inclusiveness *(education becomes more accessible for students with different needs; each student is provided with equal opportunities)*
    b. Improving teaching and learning *(students' motivation and engagement are increased, acquisition of knowledge and skills is facilitated, assessment and evaluation system is optimized, learning outcomes are improved)*
    c. Automating management processes *(automation of planning, organization, administration, controlling, HR management, etc.)*
    d. Creating enabling environments *(classrooms, labs, and/or online learning platforms are healthy, safe, stimulating and prepared to meet the individual needs of learners)*
2. Description of the idea of practice/initiative, link to the source (500 words max)
3. Initiators and implementers
4. Issues addressed
5. Role of technologies applied (300 words max)
6. Reflection on successes, opportunities or benefits provided by the use of technologies (300 words max)
7. Faced challenges and limitations (300 words max)
8. Main results and follow-ups (300 words max)

Annex 2. Distribution of the cases according to the areas of digital transformation of education and advanced ICT

Areas of digital transformation

	Area of digital transformation	Cases
1	Teaching and learning practices	3.1.1. Moscow Electronic School (Russia) 3.1.3. Virtual Labs (UAE) 3.1.4. Africa Code Week (Zimbabwe) 3.1.5. HP Innovation and Digital Education Academy Program for the Middle East & Africa (UAE) 3.1.6. PM eVIDYA Program (India) 3.1.7. Public Available Online Portal NASTAVA (Croatia) 3.1.9. Analysis of Digital Technology Use (Russia) 3.2.1. Online Platforms for Synchronous and Asynchronous Teaching (Zimbabwe) 3.2.2. TELMiE about IT (Ireland) 3.2.5. Smart Classroom Practice in Anting Elementary School (China) 3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph (China) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.9. Personalized Online Learning Support Service System (China) 3.2.10. Smart Study Center (China) 3.2.11. Accurate Teaching Efficient Learning — DigitalPen from China 3.2.13. Use of Numerical Simulation and AI to Revitalize Physics Teaching in Junior High School (China) 3.3.1. Interactive PowerPoint Presentations Played by Students on Android Phones and Smart Boards (Serbia) 3.3.2. Belgrade Adventure Project (Serbia) 3.3.3. OpenEssayist (Australia) 3.3.4. Drobik Chatbot (Russia) 3.3.5. Project “COVID-19: Equal Right to Education” (Armenia) 3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (Serbia) 3.3.9. Teaching Programming Using Specialized Digital Educational Resources (country not indicated) 3.3.11. Software Development to Improve Human Immunity System by Regulating Food Intake (UAE)

2	Organization of the educational process	3.1.1. Moscow Electronic School (Russia) 3.1.4. Africa Code Week (Zimbabwe) 3.1.6. PM eVIDYA Program (India) 3.1.10. Visual-Cloud Classroom — Promoting the Quality and Fair Development of Lifelong Education (China) 3.2.1. Online Platforms for Synchronous and Asynchronous Teaching (Zimbabwe) 3.2.3. Canvas LMS Use (Georgia) 3.2.4. Student Competency Monitoring Tool (UAE) 3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph (China) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.9. Personalized Online Learning Support Service System (China)
3	Content and curricula	3.1.7. Publicly Available Online Portal NASTAVA (Croatia) 3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph (China) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.12. Shakespeare Drama Curriculum Group Project (China) 3.2.13. Use of Numerical Simulation and Artificial Intelligence to Revitalize Physics Teaching in Junior High School (China) 3.3.2. Belgrade Adventure Project (Serbia) 3.3.5. Project "COVID-19: Equal Right to Education" (Armenia) 3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (Serbia) 3.3.7. Video Stories for Children with Disabilities and 3D Animations Using Artificial Intelligence (Croatia) 3.3.8. Critical Thinking Teaching about Media Content (Serbia) 3.3.10. Using the National Geographic Website in a Biology Class (UAE) 3.3.11. Software Development to Improve Human Immunity System by Regulating Food Intake (UAE) 3.3.12. Half-Day Inspection Course "Walking into the Humanistic Sites of Tianping Road and Hunan Road" (China)
4	Assessment practices	3.2.1. Online Platforms for Synchronous and Asynchronous Teaching (Zimbabwe) 3.2.5. Smart Classroom Practice in Anting Elementary School (China) 3.2.7. Shanghai High School Intelligent Comprehensive Evaluation System (China) 3.2.9. Personalized Online Learning Support Service System (China) 3.2.14. Research on the Evaluation of Subject Education Quality under the Background of Big Data — A Case Study of Mathematics (China) 3.3.3. OpenEssayist (Australia)

5	Professional development	3.1.2. Open Education Leadership Course (Brazil) 3.1.5. HP Innovation and Digital Education Academy Program for the Middle East & Africa (UAE) 3.1.8. Online Repository of Educational Resources for Teachers (Croatia) 3.2.2. TELMiE about IT (Ireland) 3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (Serbia)
6	Infrastructure	3.2.10. Smart Study Center (China)

Advanced ICT

	Area of digital transformation	Cases
1	Artificial Intelligence (AI)	3.1.10. Visual-Cloud Classroom — Promoting the Quality and Fair Development of Lifelong Education (China) 3.2.13. Use of Numerical Simulation and Artificial Intelligence to Revitalize Physics Teaching in Junior High School (China) 3.2.14. Research on the Evaluation of Subject Education Quality under the Background of Big Data — A Case Study of Mathematics (China) 3.2.5. Smart Classroom Practice (China) 3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph (China) 3.2.7. Shanghai High School Intelligent Comprehensive Evaluation System (China) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.9. Personalized Online Learning Support Service System (China) 3.2.11. Accurate Teaching Efficient Learning — DigitalPen (China) 3.2.12. Shakespeare Drama Course Group Project (China) 3.3.3. OpenEssayist (Australia) 3.3.4. Drobik Chatbot (Russia) 3.3.7. Video Stories for Children with Disabilities and 3D Animations Using Artificial Intelligence (Croatia) 3.3.9. Teaching Programming Using Specialized Digital Educational Resources (country not indicated) 3.3.12. Half-Day Inspection Course "Walking into the Humanistic Sites of Tianping Road and Hunan Road" (China)
2	Virtual Reality (VR) and Augmented Reality (AR)	3.1.3. Virtual Labs (UAE) 3.1.9. Analysis of Digital Technology Use (Russia) 3.2.8. Virtual Simulation Learning Platform (China) 3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (Serbia) 3.3.7. Video Stories for Children with Disabilities and 3D Animations Using Artificial Intelligence (Croatia)

3	Internet of Things (IoT)	3.2.8. Virtual Simulation Learning Platform (China) 3.2.10. Smart Study Center (China) 3.2.11. Accurate Teaching Efficient Learning — DigitalPen (China)
4	Online communication	3.1.1. Moscow Electronic School (Russia) 3.1.2. Open Education Leadership Course (Brazil) 3.1.3. Virtual Labs (UAE) 3.1.4. Africa Code Week (Zimbabwe) 3.1.6. PM eVIDYA Program (India) 3.1.7. Publicly Available Online Portal (Croatia) 3.2.1. Online Platforms for Synchronous and Asynchronous Teaching (Zimbabwe) 3.2.3 Canvas LMS Use (Georgia) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.9. Personalized Online Learning Support Service System (China) 3.2.10. Smart Study Center (China) 3.2.12. Shakespeare Drama Course Group Project (China) 3.2.14. Research on the Evaluation of Subject Education Quality under the Background of Big Data — A Case Study of Mathematics (China) 3.3.4. Drobik Chatbot (Russia) 3.3.5. Project "COVID-19: Equal Right to Education" (Armenia) 3.3.6. Innovating the Process of Teaching Geography to Increase Digital Competencies of Future Teachers (Serbia)
5	Virtual simulators	3.2.6. Construction and Application of Web3D Inquiry Learning Environment Based on Multimodal Learning Behavior Analysis and Domain Knowledge Graph (China) 3.2.8. Virtual Simulation Learning Platform (China) 3.2.12. Shakespeare Drama Course Group Project (China) 3.2.13. Use of Numerical Simulation and Artificial Intelligence to Revitalize Physics Teaching in Junior High School (China)

This report was prepared within the project "Promoting ICT Capacity Building and Open Education in the Era of Artificial Intelligence and Digital Technologies," implemented jointly by the UNESCO IITE and Shanghai Open University in 2021. The project's objective was to foster human and social development of UNESCO Member States using ICT-based innovative approaches with a particular focus on open education to expand access to relevant lifelong learning opportunities and enhance the quality of learning. The project's development and implementation were based on the idea that a comprehensive analysis and systematization of practices of digital technologies use are important for understanding the current processes and trends in the digital transformation of education and for elaborating recommendations for individual teachers, heads of educational organizations, and policymakers in education.

The leading expert: Mr. **Ivan Karlov** (Russian Federation)
Team of experts: Mr. **Diogo Amaro De Paula** (Brazil), Mr. **Maxim Bondarev** (Russian Federation) and Mr. **Anmin Yu** (China)