Consolidating Smart Education Strategies for SDG4

An Interdisciplinary Research Report on
Digital Transformation of Education

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Content

Executive Summary

This report is released in anticipation of the 2023 Global Smart Education Conference (in Beijing from 18 to 20 August) which aims to provoke discussion and discover solutions to today's challenges in education through high-level dialogues, pre-conferences, workshops, webinars and exhibitions. Past reports that guided the formulation of the current report include the UNESCO (United Nations Educational, Scientific, and Cultural Organization), HSE University (Higher School of Economics), and BNU (Beijing Normal University) joint report (2022) titled "Analytical Report on the Global Innovations and Monitoring of the Status of Smart Education" and "Smart Education Strategies for Teaching and Learning: Critical analytical framework and case studies" jointly produced by the UNESCO, COL (Commonwealth of Learning), BNU and SLIBNU (Smart Learning Institute of Beijing Normal University) in 2022.

This report delves into Smart Education amidst the technology-in-education debate, advocating for a balanced perspective. It defines performative features and constructive features of smart education . The performative aspects spotlight student-centered teaching and learning, comprehensive assessment, smart learning environments, continuous improvement culture, and inclusivity. Constructive facets focus on fostering social learning communities, supporting educators, ethical technology adoption, sustainable reform, and effective collaboration. A global policy analysis assesses diverse approaches to achieve smart education, followed by insights drawn from worldwide public data. Real-world cases illustrate digital transformations in education. The conclusion offers actionable recommendations for smart education strategies in line with Sustainable Development Goal 4 (SDG4), promoting a holistic approach to digital education.

1 Rethinking Smart Education in Response to the Debate of Technology in Education

The Demand for Education Reform

The emergence of smart education has revolutionized traditional teaching and learning paradigms, introducing a dynamic interplay of performative and constructive features that have reshaped educational landscapes worldwide. Smart education leverages cutting-edge technologies and digital tools to create immersive and personalized learning experiences, fundamentally altering the roles of educators and students (Huang et al., 2023).

This amalgamation of performative and constructive elements within smart education has transformed how knowledge is transmitted and co-created, fostering active engagement, critical thinking, and collaborative problem-solving (Huang et al., 2023). This exploration delves into the performative and constructive features of smart education, shedding light on their symbiotic relationship and the transformative potential they hold for the future of education.

The global situation of education systems calls for proactive educational reform. During the United Nations (UN) Education Summit held from September 16 to 19, 2022, UN Secretary-General Guterres emphasized the urgent need for educational system reform, stating that education is currently in a severe crisis.

Educational Digital Transformation

The Chinese representatives, during the summit, expressed its commitment further to implement the "China Education Modernization 2035" plan, prioritizing the development of education, promoting a fair and inclusive high-quality education, nurturing a new generation capable of adapting to future societal needs, building a lifelong learning education system for all, actively advancing educational digital transformation, and continuously expanding international education and cooperation ("Transforming Education Summit," 2022).

On September 20, at the United Nations Educational, Scientific, and Cultural Organization (UNESCO) 2030 Education High-Level Steering Committee meeting, Minister Huai Jinpeng mentioned leveraging digitization to drive comprehensive educational reform and vigorously promote educational digital transformation.

The preceding preparatory conferences highlighted the need to change the educational ecosystem, school forms, and teaching methods and explore educational digital governance methods to help people adapt to the digital era and achieve a more inclusive, fair, and higher-quality education development.

National Smart Education Framework

The National Smart Education Framework (Figure 1) was built to recognize the characters of smart education, to provide a reference for making smart education policies, and to promote international cooperation in smart education.

The framework is a global policy guide encompassing three leverage points which outline the implementation features of smart education: 1) technology-driven transformative teaching and learning, 2) smart digital learning spaces, and 3) progressive governance and policies. Additionally, three overarching factors are emphasized: 1) inclusivity and equity, 2) a culture of continuous enhancement, and 3) cross-sector collaboration and partnerships.

2

Digital Learning Environments Conducive to Smart Education
1. Learning Devices and Support
2. Seamless Connectivity
3. Ethical Use of Technology

1

Transformative Teaching and Learning Enabled through Technology
1. Student-Centered Pedagogy
2. Reimagined Assessments
3. Learner Community-Building

3

Forward-Thinking Governance and Policy Initiatives
1. Develop a National Vision and Plan
2. Build Infrastructure Capacity
3. Invest in Human Capacity

4

Overarching considerations across the framework
1 Inclusion and Equity
2.Continuous Improvement Culture
3.Multi-Sector Cooperation and Partnerships

Figure 1. National smart education framework (UNESCO IITE, BNU & ISTE, 2022, p. 8)

Conceptualization of Smart Education

The report by UNESCO IITE, BNU & ISTE (2022) introduced an operational definition of smart education by outlining the main concepts involved. The concept of smart education encompasses the idea of a school digital renewal process (SDRP), which tracks the transformation of schools and the education system from traditional models to the Smart School (SS) and Smart Education System (SES) models.

To provide a comprehensive understanding, a conceptual definition of smart education should elucidate the interrelationships among its sub-concepts. Consequently, the following definition of smart education emerges in the report: "Smart education is an educational process provided by smart schools in smart education systems at the regional/country level with the help of a smart educational environment" (see Figure 2).

REGIONAL

LOCAL

Smart educational environment

Smart education system

NATIONAL

Smart School
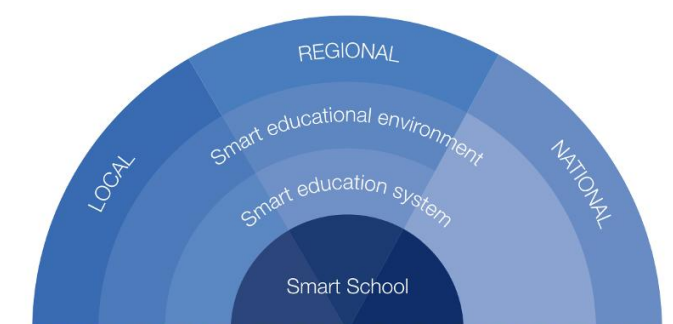
Figure 2. Conceptualization of smart education (UNESCO IITE, BNU & ISTE, 2022, p. 38)

Transforming Education Summit

Issues around the role of technology in education has been an area of concern within the past two years. The Transforming Education Summit, held at the United Nations in September 2022, was organized in recognition of the pressing global challenges facing education. These challenges encompass equity, inclusion, quality, and relevance. To address these issues, the summit identified five Thematic Action Tracks as pivotal drivers for transforming education.

These tracks focus on specific areas that require attention and action, namely, Inclusive, equitable, safe and healthy schools; Learning and skills for life, work, and sustainable development; Teachers, teaching, and the teaching profession; Digital learning and transformation; and Financing of education.

Furthermore, technology's role in education has been sparking intense debate for a long time. The new 2023 GEM Report addresses the use of technology in education around the world through the lenses of relevance, equity, scalability and sustainability.

The report raises several critical questions, such as Can technology help solve the most important challenges in education? How do we know whether technology works in education? What do countries focus on when they invest in education technology?

Purpose

Taking the previous literature into consideration, the aim of this report is to comprehensively examine and address various aspects of smart education in the context of digital transformation within the education sector. The specific aims are as follows:

· Rethink smart education with the background of the digital transformation of education
· Recognize performative and constructive features of smart education
· Conduct digital education policy analysis according to NSE framework
· Investigate influential global indicators contributing to the SDG4 National Benchmarks

2 Recognizing the Key Features of Smart Education

In the realm of education, it is essential to recognize the fundamental components of a Smart Education ecosystem (see Figure 3). This ecosystem encompasses various aspects, including evidence-based governance, technology-enhanced learning and teaching, and smart learning environments. By understanding and integrating these key features, we can foster a more effective and efficient educational system that caters to the needs of diverse learners.

By recognizing and incorporating these key features into the Smart Education ecosystem, we can create an environment that promotes evidence-based decision-making, personalized learning experiences, and optimized learning environments. This holistic approach to education empowers both educators and learners, fostering a more effective, efficient, and inclusive educational system.
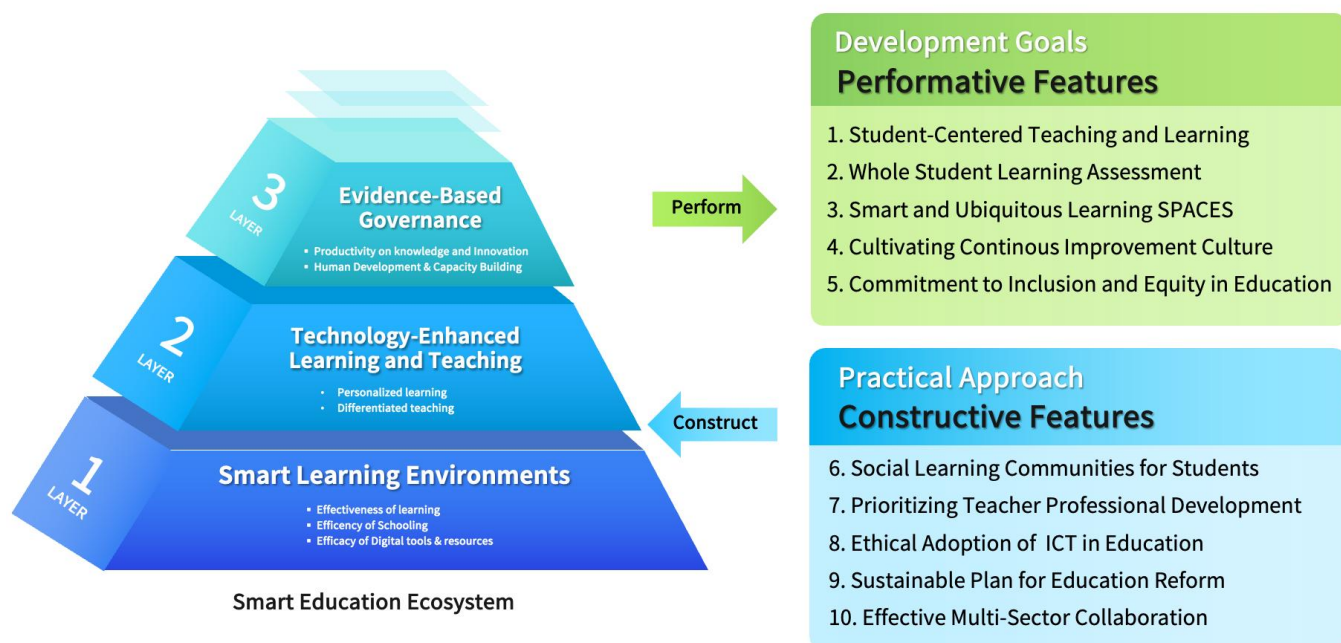
Figure 3. Recognizing the Key Features of Smart Education

Evidence-Based Governance

- Productivity on knowledge and innovation: Emphasizing the importance of research and evidence-based practices to drive knowledge creation and innovation within the educational landscape.

- Human development and capacity building: Nurturing the growth and development of individuals through strategic initiatives that enhance their capabilities and skills.

Technology-Enhanced Learning and Teaching

- Personalized learning: Harnessing technology to tailor educational experiences and content to the unique needs and preferences of individual learners, promoting their engagement and achievement.

- Differentiated teaching: Utilizing technology to facilitate varied instructional approaches and adapt teaching methods to address the diverse learning styles and abilities of students.

Smart Learning Environment

- Effectiveness of learning: Leveraging digital tools and resources to optimize the learning process, facilitating deeper understanding, critical thinking, and knowledge retention among learners.

- Efficiency of schooling: Streamlining administrative tasks, communication channels, and resource allocation through technology, maximizing operational efficiency and enabling educators to focus more on instructional activities.

- Efficacy of digital tools and resources: Ensuring that the technology integrated into the learning environment is purposeful, reliable, and supports the learning objectives, enhancing the overall educational experience.

By recognizing and incorporating these key features into the Smart Education ecosystem, we can create an environment that promotes evidence-based decision-making, personalized learning experiences, and optimized learning environments. This holistic approach to education empowers both educators and learners, fostering a more effective, efficient, and inclusive educational system.

2.1 Distinctive Attributes of Modernized Learning

Consensus Directionality Stability

From the education reform and development perspective, it has become a social consensus that education should meet the requirements of a peaceful, equitable, and sustainable future. Suppose we describe the performative features of smart education from the perspective of people's general expectations and the new form of educational development in the intelligent age. In that case, the features need to follow three principles: consensus, directionality, and stability. People have generally consistent or close views on social things and mutual relations, and it is the common understanding and value sought by people of different levels, nations, countries, and profits (Zhao, 2019). Consensus in education refers to the consistent views on the connotation and vision of education between governments and regional, intergovernmental, and non-governmental organizations. The principle of directivity refers to the educational goals jointly consisting of the international community and the development goals of China's educational modernization as the direction of the development of smart education. The principle of stability refers to the fact that education, as an essential part of culture, conforms to the characteristics of culture tending to be stable.

Consensus： A peaceful, equitable, and sustainable future

From the education reform and development perspective, it has become a social consensus that education should meet the requirements of a peaceful, equitable, and sustainable future. Suppose we describe the performative features of smart education from the perspective of people's general expectations and the new form of educational development in the intelligent age. In that case, the features need to follow three principles: consensus, directionality, and stability.

Consensus is also called social consensus; people have generally consistent or close views on social things and mutual relations, and it is the common understanding and value sought by people of different levels, nations, countries, and profits (Zhao, 2019). Consensus in education refers to the consistent views on the connotation and vision of education between governments and regional, intergovernmental, and non-governmental organizations. The principle of directivity refers to the educational goals jointly consisting of the international community and the development goals of China's educational modernization as the direction of the development of smart education. The principle of stability refers to the fact that education, as an essential part of culture, conforms to the characteristics of culture tending to be stable.

Directionality： Education 2030 Agenda and SDG4

The overall goal of the "Education 2030 Agenda" released by UNESCO is to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all," providing global guidance for education development. In 2019, the State Council issued "China's Education Modernization 2035" as a top-level educational reform and modernization design. It aligns with the values of equity, inclusiveness, and lifelong learning in the "Education 2030 Agenda," emphasizing the fundamental concepts of "for everyone," "individualized instruction," and "lifelong learning."

The effort is aimed at offering diverse learning opportunities, open and high-quality learning resources, flexible and convenient learning methods, and environmentally friendly learning environments for every individual at different stages of life, ultimately striving to establish a "networked, digital, personalized, lifelong" education system and build a society where everyone learns, everywhere is a place of learning, and learning is possible at all times (Gu et al., 2019). Smart education needs to follow this development direction, implementing the "student-centered" concept throughout the teaching process, using diverse learning assessment methods to promote learners' comprehensive development, and establishing a smart and ubiquitous learning environment to meet diverse learning needs.

Stability： Stable Educational Culture

Educational culture is the accumulated way of practicing education and the sum of its created outcomes formed through long-term development (Gu, 2006). It is an organic whole formed by various events and objects working together, always in the process of creation and evolution (Ni, 2011). The formation and development of culture mainly rely on condensation and accumulation, and the more mature a culture becomes, the greater its stability. Faced with the changes of time and the development of society, culture possesses both a regular existence and a flexible variability. Therefore, culture continues accumulating and advancing in a stable yet flexible manner (Ying et al., 2017), and educational culture is also in a stable and continuously improving development process.

In summary, inclusiveness and equity in education, a mature educational culture, ubiquitous learning environments, student-centered pedagogy, and learning assessment reforms are vital characteristics universally focused on by international organizations and the global community. These characteristics are directed toward the Education 2030 agenda and China's goals for modernizing education. Achieving them requires collective efforts from society over an extended period. They are principles marked by consensus, direction, and stability.

2.2　Foundational Aspects of Contemporary Educational Practices

Operability　Phased　Diversity

As a reform and development process of the complex macro system, education unfolds slowly and progressively. Smart education serves as the goal of digital transformation in education and the value expectations people hold for its formation and construction process. Several principles need to be considered to describe the constructive features of smart education from the perspectives of educational development and teaching practices: operability, phased, and diversity. The operability principle entails that the construction process of smart education should align with the direction of educational system transformation in the intelligence era. Within the context of the strategy for digital transformation in education, the reforms in education should be practically implemented. The phased implementation principle implies that the modes of constructing smart education should meet the requirements of new stages in educational reform and development. It should consistently address educational issues at different stages. The diversity principle signifies that the smart education system should respect the diversity of schools and students, providing adaptable support and services.

Operability：The Digital Transformation of Education

In the global education digitalization strategy context, the education system is undergoing comprehensive and systematic digital transformation. The digital transformation of education refers to the ongoing process of using digital, networked, and intelligent technologies and methods to revolutionize the education system (Huang, 2022), with technology applications within this process adhering to technological ethics. Sustainable digital transformation requires the implementation of a fully-fledged, end-to-end, all-encompassing, and cross-disciplinary digital approach within the education system (Huang, 2022), where efficient collaboration between regions and sectors will play a crucial role in realizing the digital transformation of education.

Phased：Different Stages of ICT development

Countries in the various regions of the world are at different stages of ICT development in terms of both infrastructure and application of ICT in teaching and learning. Within any such country, there may be uneven development from region to region, area to area, and even from institution to institution. Based on the UNESCO publication (UNESCO, 2002), a model has been presented that can be useful in determining the stage of ICT development reached by a country, a district, or even an individual institution. These steps are termed Emerging, Applying, Infusing, and Transforming. In the transforming new stage, it is even more important to emphasize the comprehensive and deep integration of information technology with education and teaching, highlighting the use of technology to support educational reforms, empower innovation, and drive change. The application of digital technology in education still holds immense potential, and visionary educational reform plans can help advance the use of technology to address educational issues at various stages.

Diversity：Student Diversity and Differentiated teaching

In the education system, schools of different levels, types, and conditions exhibit significant variations, and students from diverse racial, cultural, or other backgrounds also have their own distinctions. Despite the universality of educational principles, due to differences in school size, mission, internal structure, and external relationships, there is inevitably diversity in their manifestations (Zhong et al., 2011). In the context of the information age, students' learning and social spaces have expanded. Learning communities are no longer confined to traditional schools and classes but include various online learning communities. Learners from different cultural backgrounds have the opportunity for intellectual exchange. Student diversity presents opportunities to enrich the learning process and can be harnessed as educational resources (Hua, 2019). In the face of student diversity, differentiated teaching processes become particularly important. Teachers must continuously diagnose students' knowledge levels and cognitive styles to adjust their teaching methods (Bai et al., 2021). This places high demands on teachers' foundational qualities, making the effective implementation of teacher development programs crucial for enhancing teaching capabilities.

Based on the above analysis, ethically aligned technological applications, efficient collaboration between regions and sectors, visionary reform planning, diverse student social communities, and teacher capacity enhancement plans align with people's educational expectations and align with the direction of educational digital transformation. These constructive features require step-by-step implementation through national planning, mid-level deployment, and micro-level innovation. They adhere to principles of feasibility, phased implementation, and diversity.

3 Performative Features of Smart Education

Performative features encompass the dynamic and active aspects that are pivotal in shaping various domains, including education. These features involve tangible actions, behaviors, and practices those individuals and systems engage in, leading to observable outcomes. In education, performative features encompass actions such as teaching methodologies, interactive learning experiences, engagement strategies, and the utilization of technology to enhance educational processes. These features are directly linked to the active participation and behaviors of educators, students, and stakeholders within the educational ecosystem, contributing to the overall effectiveness and quality of the learning environment (see Figure 4).

1 Student-Centered Teaching and Learning

- Application of Technology to Follow Educational Needs
- Active Learning and Cultivation of Creativity
- Student Agency in the Teaching Process
- Authentic Learning beyond Textbook

2 Whole Student Learning Assessment

- Social Consensus on Student Development in the Digital Age
- Assessment of Learning
- Assessment for Learning
- Assessment as Learning

5 Commitment to Inclusion and Equity in Education

- Special Educational Needs
- Right to Education
- Student and Family Diversity
- Regional Differences

3 Smart and Ubiquitous Learning Spaces

- Ubiquitous Network Access
- Adaptive Learning Space
- Trustworthy Learning Tools
- Customize Learning Resources
- Reliable and Robust Digital Terminal
- Secure Network

4 Cultivating Continuous Improvement Culture

- Implement Evidence-based School Decision-making
- Use Technology with Purpose
- Ensure Effective Teacher Training
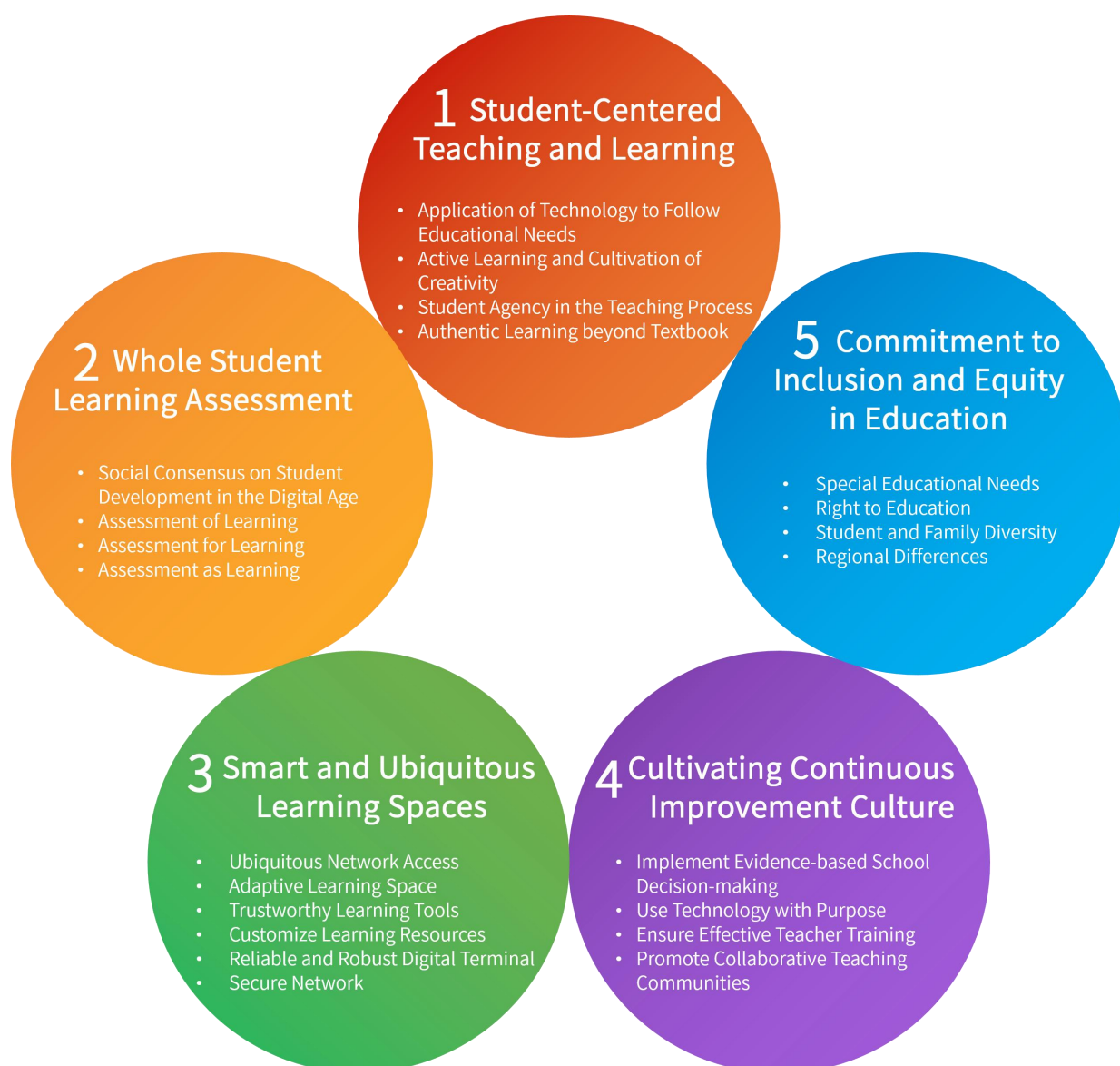- Promote Collaborative Teaching Communities

Figure 4. Performative Features of Smart Education

Performative Feature 1 : Student-Centered Teaching and Learning

While teacher-centered learning takes a traditional, didactic approach, student-centered learning (SCL) takes a constructivist, progressive approach to learning (Shehata et al., 2023). SCL is an instructional approach that places the student at the center of the learning process, emphasizing their active participation, engagement, and autonomy. The concept of "student-centered" teaching, rooted in Dewey's notion of "child-centered" education, is a novel educational paradigm (Margonis, 2009). It places students at the core of the teaching process, empowering their agency and emphasizing self-directed learning and creativity (Haiyan, 2017). This approach aims to foster learning transfer, value student outcomes and contrasts with the traditional "teacher-centered" instructional model (Huang et al., 2023).

As technology integrates into classrooms, teaching methods, models, and student learning have evolved, influenced by technology as a learning environment. Utilizing technology aligned with educational principles becomes pivotal in cultivating students (Huang et al., 2023; Mang, 2008). In today's era, talent development aligns with a fresh learning perspective, transitioning from rote memorization to real-world exploration and problem-solving. Teaching should offer diverse paths for authentic learning beyond the classroom, enabling inquiry, discussion, and meaningful connections between concepts (Huang et al., 2023; Liu, 2016). Educational technology is pivotal in facilitating SCL by providing various tools and resources that support cognitive, metacognitive, motivational, affective, developmental, social, and individual differences factors (see Figure 5).
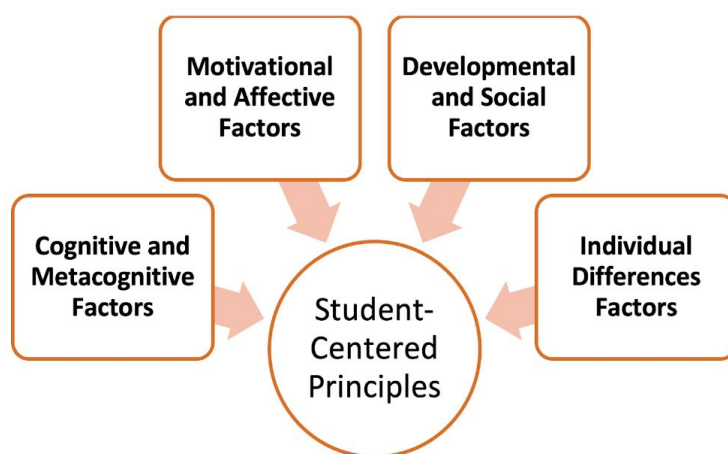
Figure 5. Student-Centered Principles (based on Shehata et al., 2023)

Application of technology to follow educational needs . The application of technology in teaching and learning improves the quality of education and promotes educational equity (Huang et al., 2023). Sustainable Development Goal 4 (SDG4) aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, which emphasizes transforming education through technology to achieve inclusive and equitable quality education (UNESCO, 2022). Technological breakthroughs provide a chance to improve access to education for marginalized people and communities, people with disabilities, refugees, those out of schools, and those living in isolated communities. Furthermore, as the "National Plan for Education Reform and Development (2010- 2020)" from the MOE of China states, IT has a revolutionary impact on the development of education which must be highly valued (MOE, 2010).

Active learning and cultivation of creativity. Technology for expression, including multimedia creation tools, blogging platforms, and presentation software, enables students to demonstrate their understanding and express themselves in various ways, promoting self-expression, communication skills, and creativity (Hourigan & Murray, 2010).

Student Agency in the teaching process. Student Agency in the Teaching Process: Student agency is central to student-centered teaching and learning. Student agency refers to students' active and emotional participation in learning paths and making decisions about their educational journey. It involves fostering an environment where students have their interests, set goals, and make informed choices about how they approach their studies. By promoting student agency, educators empower learners to become self-directed, motivated, and engaged participants in their own education (UNESCO IITE, 2022).

Authentic learning beyond textbook. Traditional education often relies heavily on textbooks as primary sources of information. However, authentic learning experiences go beyond the confines of textbooks, immersing students in real-world contexts that mirror the challenges and complexities they will encounter beyond the classroom. Authentic learning encourages students to apply their knowledge and skills to solve real problems, engage in inquiry-based activities, collaborate with peers, and connect with experts in various fields. By bridging the gap between theoretical concepts and practical application, authentic learning cultivates a deeper understanding and prepares students for success in a rapidly evolving global landscape.

Performative Feature 2 : Whole Student Learning Assessment

Learning assessment plays a vital role in the educational process by regulating the behaviors of both teachers and students during instructional activities, resulting in positive enhancements in their engagement. Teachers are advised to offer guidance and support and implement adaptive measures and learning analysis techniques to deliver personalized and timely student feedback. Simultaneously, students are encouraged to collaborate with teachers to establish learning objectives and, with appropriate guidance, choose effective ways to present their acquired knowledge and skills (Huang et al., 2023).

In 2020, the Central Committee of the Communist Party of China and the State Council introduced the "Overall Plan for Deepening the Reform of Educational Evaluation in the New Era." This plan explicitly aims to diversify evaluation methods to foster comprehensive student development. It advocates leveraging information technology extensively to elevate educational evaluation's scientific, professional, and objective aspects (Huang et al., 2023).

Learning assessment methods should be diversified and categorized as Assessment of Learning, Assessment for Learning, and Assessment as Learning to facilitate holistic student growth. "Assessment of Learning" involves summarizing interim learning outcomes, requiring teachers to analyze students' learning progress and judge their performance and achievements. "Assessment for Learning" seeks to gather evidence for learning advancement, prompting teachers to collect learning process data promptly and semi-automatically, adjust teaching strategies, and enhance instruction. "Assessment as Learning" aims to teach students self-evaluation skills during their learning journey, necessitating teachers to provide diverse learning and showcasing opportunities to encourage self-assessment and self-development (UNESCO IITE, 2022).

Social Consensus on Student Development in the Digital age. In an era marked by rapid technological advancements and global interconnectedness, the goals of education have expanded to encompass a comprehensive approach to student development. There exists a growing consensus among educators, policymakers, and stakeholders that the education system must adapt to equip students with the skills, knowledge, and values necessary to thrive in the complex and evolving landscape of the intelligence age. This section delves into the imperative of fostering a shared societal understanding and commitment to nurturing students who are academically proficient, socially aware, adaptable, and equipped to contribute meaningfully to their communities and the world.

Assessment of Learning. Students play an active role in shaping their learning objectives in collaboration with educators. They have the autonomy, guided by appropriate support, to choose how they showcase their mastery. Educators assume the role of coaches, offering assistance and utilizing adaptive measures and learning analytics to provide personalized and timely feedback. Assessments are seamlessly integrated into the learning journey and encompass various functions.

Assessment for Learning. Assessment for Learning represents a paradigm shift in assessment practices, moving from a purely evaluative approach to one that is formative, student-centered, and focused on enhancing learning outcomes. This approach views assessment as an integral part of the learning process, providing ongoing feedback and insights that inform instructional strategies and help students progress toward their learning goals. This section examines the significance of Assessment for Learning in promoting a growth mindset, fostering self-regulation, and optimizing the learning journey for each student.

Assessment as Learning. Assessment as Learning takes the student's role in assessment a step further, positioning students as active participants in the assessment process. In this model, students engage in reflective practices, self-assessment, and self-monitoring, enabling them to take ownership of their learning and development. By leveraging assessment as a means of learning, students cultivate metacognitive skills, deepen their understanding of their strengths and areas for improvement, and develop a heightened sense of agency over their education.

Performative Feature 3 ：Smart and Ubiquitous Learning SPACES

Learning environments are intertwined with teaching and learning activities, playing a pivotal role as essential settings facilitating the learning process (Gao, 2017). An intelligent learning environment represents an advanced iteration of the conventional digital learning setting, seamlessly integrating physical and virtual elements and offering tailored learning support and services based on individual learner characteristics (Huang, 2014). Creating such an intelligent learning environment encompasses six key aspects: ubiquitous network access, appropriate learning spaces, reliable learning tools, adaptive learning resources, dependable digital terminals, and a secure network environment.

Ubiquitous network access entails efficient, dependable, and uninterrupted internet connectivity accessible to educators and learners at school, home, or within the community, enabling seamless engagement with the online realm. Suitable learning spaces involve using sensor technology to monitor physical environmental factors like air quality, temperature, lighting, sound, and aromas, ensuring learners experience comfortable physical surroundings. Trustworthy learning tools safeguard students' personal information, learning process data, and copyrighted learning materials during tool usage (Zhao et al., 2021), empowering students to rely on their chosen learning tools to overcome educational challenges. Adaptive learning resources exemplify the intelligent learning environment's capacity to amalgamate learners' attributes, recognize prevailing learning context details, and furnish resources aligned with their specific learning requirements (Du, 2020). Secure digital terminals grant students convenient and secure access to educational platform services through diverse devices (Yang, 2017), mitigating unauthorized access to student information via applications. A secure network environment involves bolstering network infrastructure safeguards to guarantee the protection of critical data resources and the personal information of educators and students.

The historical evolution of educational technology has been marked by continuous advancements that have transformed the teaching and learning landscape. Future scenarios of smart and ubiquitous teaching and learning can further revolutionize educational SPACES (see Table 1).

Table 1. SPACES Acronym

SPACES	characteristics
Smart	Trustworthy Learning Tools
Personalized	Customize Learning Resources
Adaptive	Adaptive Learning Space
Connected	Ubiquitous Network Access
Environment	Reliable and Robust Digital Terminal
Secured	Secure Network

- **Ubiquitous Network Access.** The future scenario of smart and ubiquitous teaching and learning envisions seamless and ubiquitous network access. With the proliferation of high-speed internet connectivity and the Internet of Things (IoT), students will have continuous access to online resources, collaboration tools, and educational platforms. This connectivity will enable learning anytime, anywhere, breaking down time and location barriers.

- **Adaptive Learning Space.** The future of teaching and learning will witness the emergence of adaptive learning spaces. These spaces will incorporate augmented reality (AR) and virtual reality (VR) to create immersive and adaptive environments. Students can engage with digital simulations, virtual labs, and interactive experiences that adapt in real-time to their progress and performance, fostering more profound understanding and skill development.

- **Trustworthy Learning Tools.** In the future, educational technology will continue to evolve by integrating smart and intelligent tools. These tools will utilize artificial intelligence (AI) and machine learning (ML) advancements to provide reliable and trustworthy learning experiences. AI-powered algorithms will assist in curating high-quality educational content, ensuring that students have access to accurate information and resources (UNESCO, 2022).

- **Customize Learning Resources.** As technology advances, personalized learning experiences will become more prevalent. Future scenarios will involve customizing learning resources to cater to individual student needs and preferences. Adaptive learning platforms will leverage data analytics and machine learning to personalize instruction, delivering content and activities tailored to each student's strengths, weaknesses, and learning styles.

- **Reliable and Robust Digital Terminal.** The future learning environment will rely on reliable and robust digital terminals like laptops, tablets, or other internet-connected devices. These terminals will have powerful processing capabilities, extended battery life, and interactive interfaces. They will enable students to engage with multimedia content, virtual simulations, and interactive applications, enhancing their learning experiences.

- **Secure Network.** In the future, ensuring educational data's security and privacy will be paramount. Future scenarios will involve robust cybersecurity measures to protect sensitive student information, prevent unauthorized access, and safeguard online learning environments. Encryption, multi-factor authentication, and secure communication protocols will be integral to creating secure educational networks.

Performative Feature 4 : Cultivating Continuous Improvement Culture

Educational culture is a foundational guide for educational reform, and its enhancement should permeate every facet of the education system. At the school level, a focus on continuous improvement is crucial to adapt to changes in the educational system (Liang, 2010). School improvement involves reshaping the internal environment and related factors to more effectively achieve educational goals (Van Velzen, 1985). In the intelligence era, schools must collaborate with stakeholders, gather pertinent information about information technology infrastructure, educational content, and teacher professional development, and create sustainable and scalable "technology-enabled learning."

To begin, School reform demands rigorous research and ensures students' involvement in the improvement process, as their perspectives contribute to practical school enhancements and foster introspection in school development (Lu, 2007). Secondly, The motivation behind technology use should be grounded in achievable expectations, focusing on how technology can address educational challenges. Technological applications in education should align with educational principles and phenomena (Chen, 2021). Thirdly, Teacher training should follow scientifically sound instructional design and utilize materials aligned with learning principles. Lastly, avoiding isolation in educational research communities is crucial. Strengthening collaboration among universities, research institutions, schools, and other entities fosters an open and efficient research community that works synergistically, promoting advancement in educational research (Liu, 2022).

- **Implement evidence-based school decision-making.** Effective educational reform requires well-informed decisions grounded in rigorous research and a deep understanding of the academic context. Arbitrary decision-making within schools can hinder progress and undermine the potential benefits of reform efforts. It is essential to move beyond random choices and adopt a data-driven approach that ensures decisions align with the overarching goals of enhancing the education system.

- **Use Technology with purpose.** The integration of technology into education has the potential to revolutionize learning experiences. However, the haphazard or aimless application of technology can lead to inefficiencies and missed opportunities. To harness the power of technology, educational institutions must have a clear vision of how these tools align with educational objectives. Thoughtful and strategic technology implementation can drive meaningful improvements in teaching and learning.

- **Ensure Effective Teacher Training.** Teachers are pivotal in shaping students' educational experiences. Therefore, their professional development must be comprehensive, effective, and aligned with evidence-based practices. Ineffective teacher training programs can hinder the growth of educators and limit their ability to meet the evolving needs of students. A culture of continuous improvement demands that teacher training is based on pedagogical research and designed to enhance classroom practices.

- **Promote collaborative teaching communities.** Promote collaborative teaching communities and exchanging ideas among educators are vital for promoting innovation and best practices. Isolating teaching communities prevents sharing insights, experiences, and effective strategies. Avoiding separate teaching communities necessitates a focus on creating a cohesive network where educators from different backgrounds and institutions can connect, share, and learn from one another.

Performative Feature 5: Commitment to Inclusion and Equity in Education

Inclusiveness and equity are fundamental pillars of high-quality education. Smart education must address the needs of both students and educators, promoting representation from diverse communities in crucial decision-making processes. The advancement of inclusive, equitable, and resilient education necessitates greater involvement from various spheres, including learning, culture, and society. This collective effort aims to establish a consensus of "zero refusal, zero exclusion" to minimize instances of exclusion within and beyond the education system (Heyan, 2019).

Also, it is imperative to overcome obstacles that impede students' access to educational opportunities, active engagement in the learning journey, and attainment of learning objectives. Equal access to education should be afforded to every eligible child. Customizing classrooms and providing instructional support for students with special educational needs fosters their successful integration into mainstream classrooms. Embracing the diversity among students and families, appreciating the advantages of such diversity, and regarding individual differences as opportunities to enhance the learning experience and drive educational innovation are pivotal principles (UNESCO, 2019).

- **Special Educational Needs.** In education, a fundamental principle is providing access and support for individuals with special educational needs. This entails integrating these students into regular schools, where a child-centered approach is adopted to cater to their unique requirements. The concept of inclusion emphasizes the importance of keeping special education students in mainstream classrooms and bringing necessary support services directly to the child. As highlighted by Ruijs and Peetsma (2009), this approach shifts the focus from relocating the child to support services to making support services more accessible within the child's educational environment (Ruijs & Peetsma, 2009). The overarching goal is to create an inclusive and accommodating educational setting that addresses the diverse needs of students with special academic requirements.

- **Right to Education.** Subrahmanian (2005) identifies three interconnected dimensions of rights in the context of education: rights to education, rights within education, and rights through education. "Rights to education" encompass the fundamental entitlement of individuals to access quality education. "Rights within education" pertain to ensuring equitable treatment, non-discrimination, and a conducive learning environment for all learners. "Rights through education" refer to education's transformative potential to empower individuals to exercise their rights and contribute to societal progress. These dimensions highlight the comprehensive nature of educational rights, encompassing access and the quality, inclusivity, and transformative impact of education (Subrahmanian, 2005).

- **Student and Family Diversity.** The engagement of diverse families and their involvement in schools is crucial to fostering inclusivity and equity in education. Garcia (2014) explores how schools support various family backgrounds and define parental involvement, highlighting the importance of considering factors such as ethnicity, race, gender, and class. Understanding how parents from diverse backgrounds engage with schools is essential for creating an inclusive and supportive learning environment.Moreover, teachers play a pivotal role in addressing the needs of students from diverse family backgrounds. Gichiru (2016) emphasizes the significance of teachers acquiring knowledge about the complexities and evolving structures within families. By gaining insights into these dynamics, educators can better tailor their approaches to cater to the diverse needs of their students, ultimately enhancing the overall educational experience (Gichiru, 2016). A participatory design approach is recommended to bridge the gap between culturally and linguistically various families and the dominant school culture. This approach, as highlighted, aims to establish trusting relationships between families and teachers, despite existing inequities. This process encourages collaborative efforts and paves the way for mutual understanding and respect among all stakeholders.

- **Regional Differences.** The concept of inclusive education is subject to significant variations in its interpretation at both national and regional levels. The understanding of inclusive education can differ, with some viewing it as a matter of organizational structure and others considering it a methodological approach. As discussed by Meijer and Watkins (2019), this interpretational variability underscores the diverse perspectives and approaches taken toward implementing inclusive education, reflecting the complexity of integrating students with diverse needs into the educational system (Meijer & Watkins, 2019).

4 Constructive Features of Smart Education

Constructive features play a pivotal role in shaping the landscape of smart education, where technology and innovation converge to enhance learning experiences (see Figure 6). These foundational elements are instrumental in successfully implementing smart education initiatives, ensuring a dynamic and effective learning environment. Within smart education, constructive features encompass a range of essential components.

Curriculum design takes on a new dimension, integrating digital tools to create adaptable and interactive learning materials. Pedagogical approaches evolve, leveraging technology for active learning and collaborative problem-solving. Data-driven insights facilitate informed decision-making, tailoring instruction to individual student needs. Personalized learning takes center stage as smart education platforms offer tailored content and adaptive pathways. Collaborative learning is empowered through virtual classrooms and collaborative project tools, fostering teamwork and communication skills. Accessibility and inclusivity are prioritized, with user-friendly interfaces and assistive technologies catering to diverse learners. Continuous professional development ensures educators are equipped to navigate the digital classroom effectively. Constructive feedback mechanisms provide real-time insights into student progress, enabling timely interventions. Emerging technologies like AI, VR, and AR enrich learning experiences, making them immersive and engaging. Sustainability and scalability considerations underpin smart education's success, encompassing infrastructure, technical support, and long-term planning. These constructive features create a foundation that drives technology integration, fostering a dynamic and impactful learning environment. By integrating these elements, smart education endeavors to equip students with the skills and knowledge necessary for a rapidly evolving digital landscape.

6 — Social Learning Communities for Students

- Technology-mediated culturally responsive teaching
- Social-emotional skills in social network
- Enhanced digital literacy and skills

7 — Ethical Adoption of ICT in Education

- Personal privacy data and information security
- Secure and orderly data flow between systems
- Scenario-based artificial intelligence ethics
- Algorithmic interpretability in educational systems

8 — Prioritizing Teacher Professional Development

- Global digital skills standards for teachers
- Technology application among pre-service teachers
- Technology-enabled training for in-service teachers
- Assurance of time and funding for teacher training

9 — Sustainable Plan for Education Reform

- Consensus sustainable development vision
- Iteratively updated information infrastructure
- Object-oriented digital resource aggregation mechanism
- Innovative technology adoption in educational disciplines

10 — Effective Multi-Sector Collaboration

- Adaptive removal of barriers to educational reform
- Intelligent technology integration into educational social experiment
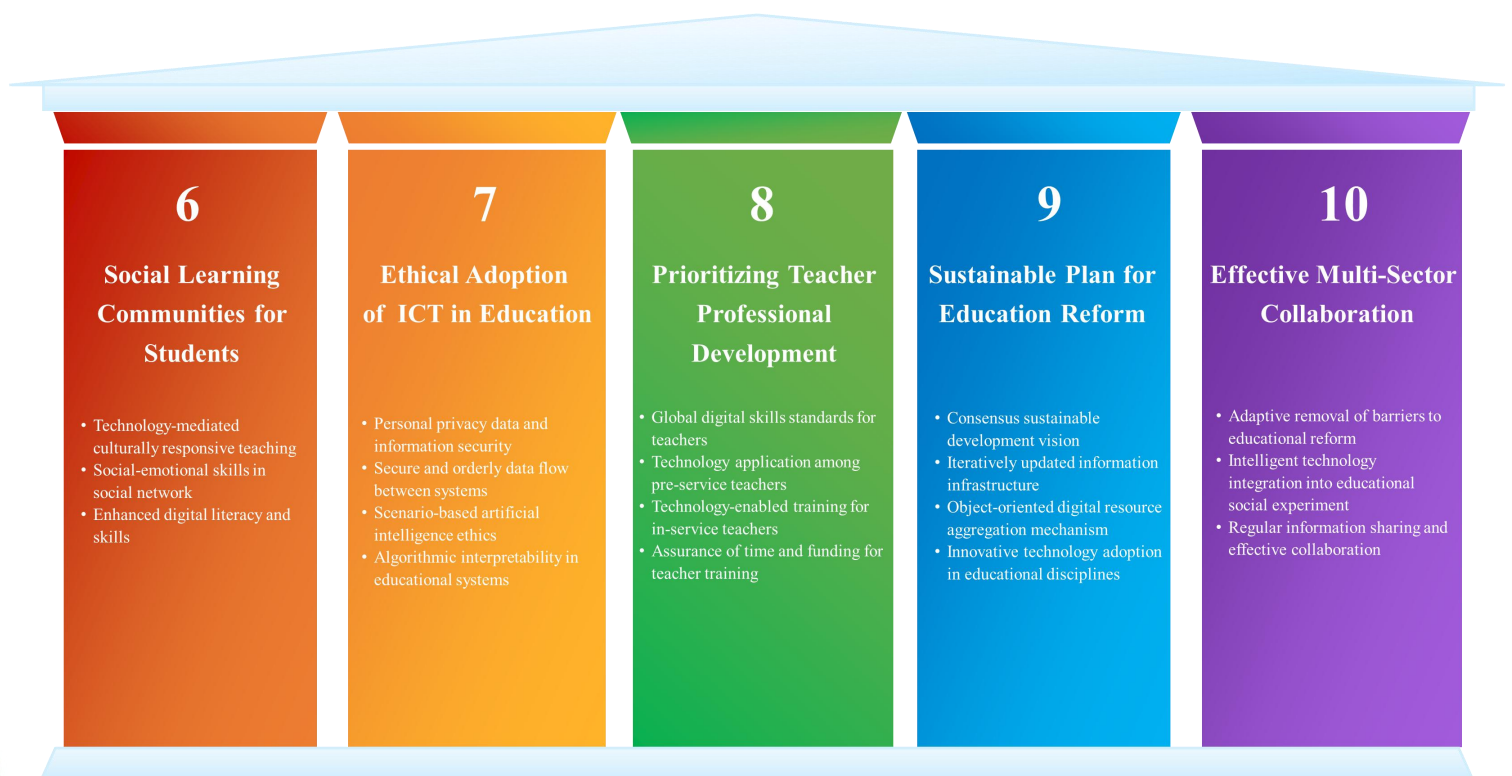- Regular information sharing and effective collaboration

Figure 6. Constructive Features of Smart Education

Constructive Feature 1： Social Learning Communities for Students

Non-cognitive skill development is currently a significant focus in global education, with social-emotional learning receiving widespread recognition. Social-emotional learning primarily involves understanding emotions within individual thinking and social interactions, encompassing self-awareness, self-management, social awareness, interpersonal skills, and responsible decision-making. The Washington Social-Emotional Learning Work Group introduced "culturally responsive" teaching, integrating students' diverse cultural backgrounds, experiences, and viewpoints into instruction, enhancing teaching quality, and fostering identity and engagement.

Technology is pivotal in shaping culturally responsive teaching, enabling students to expand their learning beyond classrooms to society and the global community. This facilitates comprehension of diverse cultures, an appreciation for diversity, and the development of a cultural identity, transforming learners into global citizens. In the digital age, citizenship encompasses digital citizenship, enhancing digital literacy and skills, using technology responsibly, participating in societal activities, and contributing to societal progress. These elements are essential to digital citizenship education (Yang Hao, 2016).

- **Technology-mediated culturally responsive teaching.** Technology Supported Culturally Responsive Teaching is an instructional strategy that seamlessly incorporates technology into teaching methods, aiming to establish an all-encompassing and culturally aware learning environment. By recognizing students' diverse backgrounds and utilizing technology, this approach customizes education to address individual requirements, ultimately promoting a more profound comprehension of various cultures and perspectives.

- **Social-emotional skills in social network.** The concept of Social Emotional Skills in Social Networks underscores the significance of emotional intelligence in the modern digital era. It emphasizes nurturing social-emotional competencies in online engagements, specifically cultivating traits like empathy, proficient communication, and emotional strength within digital social networks.

- **Enhanced digital literacy and skills.** The Improvement of Digital Literacy and Skills component goes beyond mere technical expertise, emphasizing enhancing students' digital literacy. It encompasses critical thinking, ethical awareness, and responsible digital citizenship. By fostering these competencies, students are empowered to navigate the intricate landscape of the digital realm with effectiveness and ethical responsibility.

Constructure Feature 2: Prioritizing Teacher Professional Development

Teachers play a central role in implementing smart education and are essential to its success. The advancement of smart education necessitates a teaching workforce proficient in digital literacy and advanced pedagogical skills. Merely investing in digital technology equipment and resources is insufficient for genuine transformation; government-led and funded initiatives like pre-service teacher training, continuous professional development, and ongoing learning support are pivotal for effective educational digital transformation.

Key strategies for teacher development include: Establishing professional development standards to design, assess, and fund teachers' learning and training. Encouraging experiential workshops that empower teachers with technology, fostering cross-regional and cross-school collaboration. Providing sustained duration and financial support for teacher training through workshops, seminars, and conferences. Conducting regular surveys to identify teachers' professional development needs and ensure training aligns with practical application. Selecting and nurturing expert teachers to mentor and coach others, integrating them into school improvement plans. Redesigning school schedules to provide more teacher professional development and collaboration opportunities, including peer mentoring, classroom observations, professional learning communities, and collaborative research.

- **Digital Skills Standards for Teachers.** Digital Skills Standards for Teachers encompass a set of competencies that educators need to incorporate technology into their teaching methods adeptly. These standards guide for teachers to cultivate robust digital literacy. Key aspects encompassed by these standards include technical proficiency, enabling teachers to use relevant digital tools, software, and applications proficiently. Effective digital communication skills enable educators to engage students and colleagues via digital platforms. Information literacy empowers teachers to critically evaluate and curate digital content, ensuring its credibility and relevance. Digital citizenship knowledge provides ethical conduct in the digital realm, addressing privacy, online safety, and copyright concerns. Lastly, pedagogical integration emphasizes leveraging technology to elevate teaching and learning experiences, encompassing multimedia presentations, interactive assessments, and online discussions (UNESCO, 2022).

- **Technology Application o Pre-service Teachers.** Technology Application in Pre-service Teacher Training is designed to equip aspiring educators with the skills to utilize technology in their classrooms effectively. This includes integrating technology into the curriculum to align with educational objectives and fostering engaging and personalized learning experiences. Future teachers are trained in digital pedagogy, embracing innovative teaching methods that capitalize on technology for active student participation. They learn to employ technology for assessments, analyzing student progress data, and delivering timely feedback. Moreover, pre-service teachers acquire the ability to navigate evolving technological landscapes, ensuring they can adapt to new tools and trends in the digital realm (Oubibi, 2023). This comprehensive approach empowers them to become tech-savvy educators who enhance the learning journey through the seamless integration of technology (UNESCO IITE, 2022).

- **Assurance of time and funding for teacher training.** Ensuring teacher training time and funding is crucial for effective technology integration. This involves allocating dedicated time for training sessions and workshops, providing adequate funding to cover training costs and access to technology tools, offering flexible training scheduling to accommodate teachers' availability, ensuring a long-term commitment to ongoing professional development, acknowledging the evolving nature of technology and the need for continuous learning.

Constructive Feature 3: Ethical Adoption of ICT in Education

Pursuing smart education requires a careful balance between safeguarding personal information and enabling authorized access. Educational data privacy must address the paradox of protection and open sharing, ensuring data security while allowing approved individuals like students, teachers, and leaders to access it. Student privacy data must be consistently safeguarded and used selectively for credible purposes like personalized learning or research. Achieving data interoperability for enhanced teaching involves implementing seamless, secure protocols between different systems.

Regarding artificial intelligence ethics, AI tools for learning, teaching, and school management should proactively prevent potential risks like misuse or overuse. Algorithm interpretability within education should prioritize reliability, control, transparency, and inclusivity. This approach ensures that intelligent technology applications in education are dependable, comprehensible, and manageable (Wang, 2021).

- **Personal privacy data and information security.** Ensuring the confidentiality and security of personal data and information is paramount. Robust measures should be in place to safeguard sensitive data and uphold the privacy rights of students and stakeholders.

- **Secure and orderly data flow between systems.** The seamless and secure transfer of data between different systems is crucial. Establishing protocols and standards for data exchange ensures a reliable and organized flow of information, minimizing the risk of breaches or data loss.

- **Scenario-based artificial intelligence ethics .** Ethical considerations surrounding artificial intelligence (AI) applications should be context-specific. Adhering to scenario-based AI ethics involves assessing AI tools' potential risks and benefits in various educational scenarios to ensure responsible and unbiased use.

- **Algorithmic interpretability in educational systems**. The transparency and interpretability of algorithms used in educational systems are essential. Algorithmic decisions should be understandable and justifiable, enabling educators and stakeholders to comprehend and trust the outcomes of algorithmic processes.

Constructive Feature 4: Sustainable Plan for Education Reform

Creating a sustainable national education reform plan requires forward-looking policies that leverage technology effectively. Governments should establish a vision for sustainable development, acknowledging digital technology's positive impact on student growth, educational equity, and socio-economic advancement. This vision should lead to a lasting action plan. Emphasizing sustainable education, the plan should prioritize fostering students' digital skills and lifelong learning abilities. Key objectives are empowering teachers to use digital teaching methods and enhancing students' adaptability in the digital age (UNESCO IITE, 2022).

Infrastructure-wise, ensuring secure and efficient digital foundations demands widespread deployment, continuous maintenance, and timely updates of educational technology. Standardizing resources is crucial for promoting and using digital materials and textbooks on a large scale. Thus, creating high-quality digital resources and guidelines for developing digital textbooks is vital. Advancing technology must align with educational principles and boost learners' efficiency, experience, and benefits. Encouraging cutting-edge digital learning technologies is essential for sustainable development (Zhao, 2021).

- **Consensus sustainable development vision.** The call for reevaluating sustainable development's meaning for Africans within their diverse contexts is a foundation to explore educational philosophies and pedagogies that address Africa's unique challenges. UNESCO emphasizes education as a pivotal tool for achieving Sustainable Development Goals (SDGs), fostering knowledge, skills, values, critical thinking, and systemic understanding to empower future generations for transformative change. Higher education's role in generating innovative ideas and sustainable technologies is significant, yet its societal contribution might be underestimated. Despite personal interest, academics encounter barriers like time constraints, lack of resources, curriculum structures, and organizational support that hinder their involvement in Education for Sustainable Development (UNESCO IITE, 2022).

- **Iteratively updated information infrastructure.** Information infrastructure encompasses technological tools, methods, and access models essential for efficient knowledge management and transfer in the era of vast information flows. It comprises information and communication technology like computers, software, and telecommunication components, facilitating widespread sharing and utilization of resources. In the digital age, this infrastructure can enable the creation, preservation, organization, and access to cultural knowledge within the network society. However, while industrialized economies experience an explosion of information and infrastructure use, developing regions, notably Africa, face "information poverty." These areas lack strategic information crucial for health, industries, social services, governance, environment, and sustainable development, often relying on external sources for their local information needs (UNESCO IITE, 2022).

- **Object-oriented digital resource aggregation mechanism.** Digital resources and technologies are crucial in realizing the United Nations' sustainable development goals for 2030(Sparviero & Ragnedda, 2021). The COVID-19 pandemic has accelerated the integration of digital technologies into education, solidifying their institutional importance (Haleem et al., 2022).

- **Innovative technology adoption in educational disciplines.** Digital technologies and innovative solutions are pivotal drivers of sustainable development. Yet, their effects encompass a dual spectrum of benefits and drawbacks, warranting recognition of their potential positive and negative implications for sustainability (Al-Emran et al., 2023).

## Constructive Feature 5： Effective Multi-Sector Collaboration

Intelligent technology has facilitated multi-sector collaboration within public education services, thereby expanding the scope of educational provision (Zeng, 2017). Collaborative efforts between government-led entities, businesses, higher education institutions, research establishments, and other stakeholders have culminated in effective strategic partnerships. Framed as a public good, education assumes the role of disseminating knowledge and resources, collectively catering to educational institutions and educators' needs, with the overarching objective of propelling transformative technological implementations within the educational domain. It is emphasized that the application of smart technology should transcend restricted educational settings, embracing broader societal contexts (Lu, 2022).

Notwithstanding the pivotal role of technology in propelling educational reform and progress, its integration into the educational sphere is not devoid of challenges (Zhang, 2019). Various factors, including students' cognitive aptitudes towards novel technology, pre-existing knowledge, technological compatibility, and alignment with instructional objectives, collectively influence the acceptance and adoption of specific smart technologies by educators and learners (Gao, 2009). Consequently, the imperative arises for adaptive strategies that surpass mere technological promotion, surmounting obstacles to facilitate students' efficacious integration of technology for pedagogical purposes. cutting-edge digital learning technologies is essential for sustainable development (Zhao, 2021).

- **Adaptive removal of barriers to educational reform.** Collaborative efforts across different sectors aim to identify and eliminate barriers that hinder educational reform (Cheung & Wong, 2012). By adapting policies and practices, stakeholders can collectively address challenges and facilitate the implementation of innovative strategies.

- **Intelligent technology integration into educational social experiment.** Integrating intelligent technology into educational, social experiments allows for real-world testing and refinement (Luckin & Holmes, 2016). Collaborative initiatives between technology developers, educators, and researchers enable the exploration of technology's impact on learning outcomes and pedagogical approaches.

- **Regular information sharing and effective collaboration.** Establishing channels for regular information sharing and collaboration enhances coordination among stakeholders. By exchanging insights, best practices, and research findings, different sectors can work together to drive educational improvements and optimize the use of intelligent technology (LaValle et al., 2010).

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5 Global Educational Policy Analysis for Achieving Smart Education

This section summarizes the results from a digital education policy analysis according to the National Smart Education (NSE) framework. The analysis included national policies or programs related to ICT in education and digital education from various countries worldwide (see Figure 7).

Source: https://www.un.org/geospatial/content/map-world
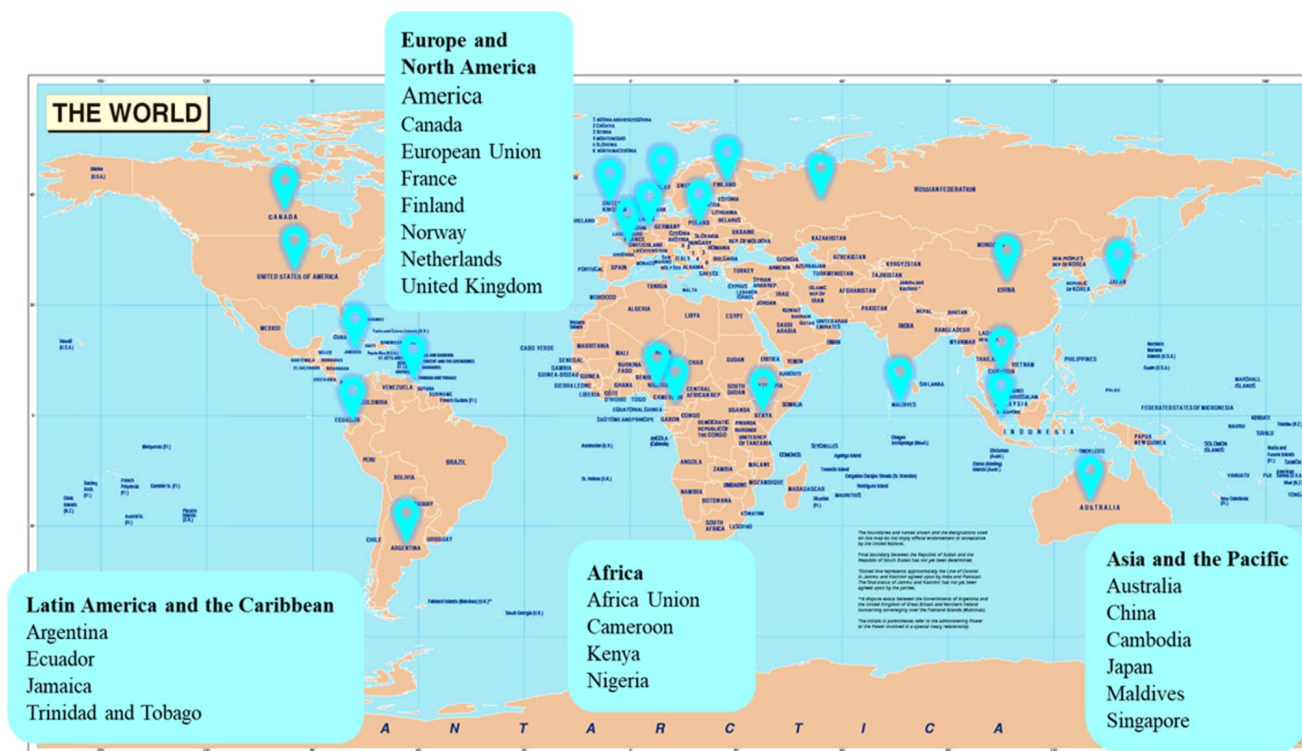
Figure 7. Policy collection

The initiatives of select global nations were reviewed and summarized to probe common trends, key development directions, and measures across different continents. A research group of 11 individuals participated in locating, discussing, and analyzing the relevant policy texts.

Table 2. Policy collection list by Country/Organization

Country/Organization	Policy Title	Published Time
African Union	Digital education strategy	2022
Argentina	National integral plan of digital education (PLANIED)	2017
Cambodia	Policy and strategy on information and communication technology in education	2018
Cameroon	ICT policy and strategic framework for education base in Cameroon	2022
Ecuador	Digital education agenda 2021 - 2025	2021
European Commission	Digital education action plan 2021-2027	2020
Finland	Policies for the digitalisation of education and training until 2027	2023
France	Digital agenda for education 2023-2027	2023
Jamaica	ICT in education policy	2022
Japan	Roadmap on the utilization of data in education	2022
Kenya	Policy on information and communication technology in education and training	2021
Maldives	ICT in education master plan 2 2021-2024	2021
Netherlands	Digitalisation agenda for primary and secondary education	2019
Nigeria	National policy on information and communication technologies (ICT) in education	2019
Norway	Digitalisation strategy for basic education 2017-2021	2017
Quebec	Digital action plan for education and higher education	2018
Singapore	Educational technology plan 2020-2030	2019
South Australia	Digital strategy 2023 to 2026	2023
Trinidad and Tobago	Digital transformation programme	2022
United Kingdom	Realising the potential of technology in education: A strategy for education providers and the technology industry	2019
United States	National education technology plan	2017

Digital Education Policy Analysis

By analyzing several of the sampled policies, each country focused on seamless network connectivity, learning devices and support, and ethical use of technology in the context of smart education environments. South Australia, Singapore, Cambodia and the Maldives all mentioned building a seamless internet-connected environment. South Australia offers internet connectivity, Singapore supports connected and personalized learning, Cambodia connectivity, and Maldives internet connection. internet connection was requested by Singapore, connectivity by Cambodia, and internet connection by Maldives.

A modernized digital learning ecosystem requires a strategic, long-term commitment from government leaders to develop a national vision and plan for the effective use of educational technology, as well as adequate investments to ensure the plan's effective, sustainable implementation and continuous improvement. Are educators and leaders collaborating with stakeholders to continuously collect information on and evaluate educational experiences — including the effectiveness of technology infrastructure, learning content, and professional development — in supporting the broader vision around technology-empowered learning?

The concept of "Commitment to Inclusion and Equity in Education" was observed in several contexts. For example, in the context of the African Union's Digital education strategy, it was exemplified by the following :

- ✓ The strategy aims to guarantee access to learning opportunities through ICT for every child and adult, emphasizing inclusivity and equity in education.

- ✓ The vision of a peaceful and prosperous Africa, integrated and led by its own citizens, highlights the importance of providing equal educational opportunities to all individuals, regardless of their background or circumstances.

- ✓ The mission of harnessing digital technologies to achieve strategic objectives, including inclusion and equity, emphasizes the commitment to ensuring that education is accessible and beneficial for all learners.

- ✓ The strategy objectives include promoting an enabling infrastructure, developing curriculum-aligned digital content, expanding capacities of Member States, advancing data management and analytics, promoting entrepreneurship and innovation, facilitating research cooperation, and promoting digital literacy and skills for teachers, students, communities, and leaders.

- ✓ The mobilization of resources for bolstering digital education in Africa demonstrates the commitment to providing necessary funding and support to ensure equitable access to quality education.

- ✓ The emphasis on partnerships, collaboration, and resource mobilization underscores the collective efforts of African nations to advance digital education while ensuring its quality, sustainability, and accessibility.

- ✓ Inclusion and equity are key considerations throughout the policy documents, reflecting the commitment to ensuring that all individuals have equal opportunities to benefit from digital education initiatives.

Social Learning Community

The concept of social learning community for students involves technology-supported culturally responsive teaching, social-emotional skills in social networks, and improvement of digital literacy and skills. For example, the French Ministry of Education launched the "Digital agenda for education 2023-2027" in March 2023, with a focus on building a secure and reliable educational community. The agenda includes measures to enhance users' awareness of digital risks and cybersecurity, such as educating and training students to understand and address these risks. The Pix 6 device certification program will be implemented, incorporating specific courses on protection and security. Additionally, efforts will be made to prevent cyberbullying and promote responsible use of social networks, including the dissemination and compliance with a charter for education in digital culture and citizenship. Interoperability of tools and resources, user approaches for products, and the promotion of ecologically responsible digital technologies are also prioritized.

Prioritizing Teacher Professional Development

For the prioritizing teacher professional development, in March 2019, the "Digitalization agenda for primary and secondary education" (MoE, 2019) of the Dutch Ministry of Education, Culture and Science mentioned that digitization not only offers opportunities for improving education, but at the same time calls on education to work towards developing the digital literacy of pupils. Teachers, principals, and administrators innovate by learning with others: To improve education, teachers and principals need to learn from one another, both from good practices and from mistakes. Netherlands proposed that teachers and principals need to learn from each other, improve, and innovative teaching methods.

Cybersecurity for the development of digital education

Several countries emphasized the importance of cybersecurity for the development of digital education: France proposed the prevention of cyberbullying and the enhancement of users' awareness of digital risks and cybersecurity; The European Commission stressed the need for developing ethical guidelines on artificial intelligence and data usage in teaching and learning for educators; The UK Department for Education published a data protection toolkit to mitigate the privacy, security and safety implications that come with adopting technology; Netherlands sustained focused on the ethics of digitization in education; Quebec raised awareness of online security issues among internet users through the digital citizenship website; Norway highlighted safeguarding the privacy of communication devices; the United States formulated Develop Responsible Use Policies (RUP).

Multi-sectors collaboration

Government leaders have the opportunity to leverage the broad reach and influence of private and social sectors, higher education institutions, and domestic and international non-governmental organizations to provide public services that promote the transformative use of technology in education. Collaborative models involving these sectors can be employed to overcome barriers to student learning with technology, experiment with innovative approaches, and accelerate the scaling of evidence-based solutions. It is crucial to strategically incentivize multi-sector partners to contribute their knowledge and resources for the benefit of the public good.

It is worth mentioning that the Ministry of Education (MOE) in China initiated educational digital transformation strategy since 2022, where Minister Huai Jinpeng, proposed the "3C" concept of Connection, Content and Cooperation, and highlighted that "Application, Service, Efficiency and Security" are four keywords for promoting educational digital transformation. In 2022, a on the Digital Development of Global Higher Education was also released by the MOE during the World MOOC and Online Education Conference. The objectives were as follows:

- ✓ Adopt a more people-centered education philosophy
- ✓ Build a more intelligent education process.
- ✓ Adopt more diversified approaches in education evaluation.
- ✓ Foster an educational culture that values openness and connectivity.
- ✓ Provide individualized education services.
- ✓ Build a higher education system that values sustainability.

In conclusion, the digital education policy analysis indicates: (1) policies in different countries reflect different stages of digitization, digitization, digital transformation, and (2) there are some common characteristics in the four dimensions of smart education within each specific stage (see Figure 8).

	Digitization	Digitalization	Digital transformation
Forward-Thinking Governance and Policy Initiatives	• ICT infrastructure • ICT knowledge and skills	• Sustainable and inclusive digital offer • Improve digital services • Digital learning experiences	• High-quality, inclusive and accessible education • A high-performing digital education ecosystem
Digital Learning Environments Conductive to Smart Education	• Wi-Fi coverage area • Digital learning resources and equipment	• Reorganize physical space • Age-appropriate access to devices • Mobilize data at the service of the school	• Develop ethical guidelines on artificial intelligence and data usage • Ubiquitous connectivity • Seamless learning
Transformative Teaching & Learning Enabled through Technology	• ICT-based skills • E-learning	• Cooperative learning and co-creation among students • Use assessment data to improve learning	• Harness technology for learner-centred assessments • Real-Time Feedback • Computational thinking
Smart Education Overarching Considerations	• Equal access to learning opportunities • Tackle gender stereotypes and gender bias	• Putting digital at the service of Inclusive schools • Clarification of sectoral responsibilities	• Digital awareness • Cross-sectoral collaboration • Close the digital divide

Figure 8. Digital Education Policy Analysis according to NSE framework

6 The Insight of Smart Education from Global Public Data Source

6.1 Analyzing the Interplay Between Smart Education and SDG 4

In the pursuit of sustainable development, achieving Goal 4 of the United Nations' Sustainable Development Goals (SDGs) - Quality Education - is of paramount importance. With the rise of technology, the concept of smart education has gained momentum, promising innovative approaches to enhance learning outcomes.

Global organizations and countries have made various efforts in the digital transformation of education, including the establishment of a digital learning environment, investment in human resources, and comprehensive governance of education. In recent years, there has been an increasing amount of survey data related to the digital transformation of education. In order to provide more quantitative insight for the digital transformation of education, this section aims to conduct a systematic analysis of diverse data, such as student abilities, seamless network infrastructure (e.g., ICT), investment in education funding, inclusive education, research, governance, and well-being indicators. This analysis will identify a) the relationship between smart education and SDG 4 national benchmarks, which are targets related to seven indicators that countries have committed to achieve by 2025 and 2030; b) the contribution of smart education to PISA scores, through data analysis with data compilation in global public data sources.

6.2 Data Compilation from Global Public Data Relevant to Education

The SDG 4 National Benchmarks data reviewed 206 countries and regions, providing the national targets that countries have set themselves to be achieved by 2025 and 2030 on seven key education indicators.

PISA 2018 Results (Volume I) to PISA 2018 Results (Volume VI) examines approximately 80 countries and regions on what students know in reading, mathematics and science. Results from PISA indicate the quality and equity of learning outcomes attained around the world.

The World Development Indicators (WDI) contains 1,400 time series indicators for 217 economies and more than 40 country groups, with data for many indicators going back more than 50 years.

The UNESCO Institute for Statistics (UIS) produces a wide range of state-of-the-art databases which list 11 global indicators to monitor SDG 4 adopted by the UN General Assembly for 67 countries and regions.

The Teaching and Learning International Survey (TALIS)2018 is an international survey of 46 countries and regions that offers the opportunity for teachers and principals to provide input into education analysis and policy development.

The Network Readiness Index 2022 (NRI2022) comprises four pillars, twelve sub-pillars, and fifty-eight indicators, and it surveyed 131 countries and regions to determine the overall rankings.

According to the report features and data sources, we suggest data compilation structure for smart education with four leverage points, including transformative teaching & learning enabled through technology (TLT), digital learning environments conducive to smart education (SLE), forward-thinking governance and policy initiatives (FGP) and smart education overarching considerations (SEO) (see Figure 9).
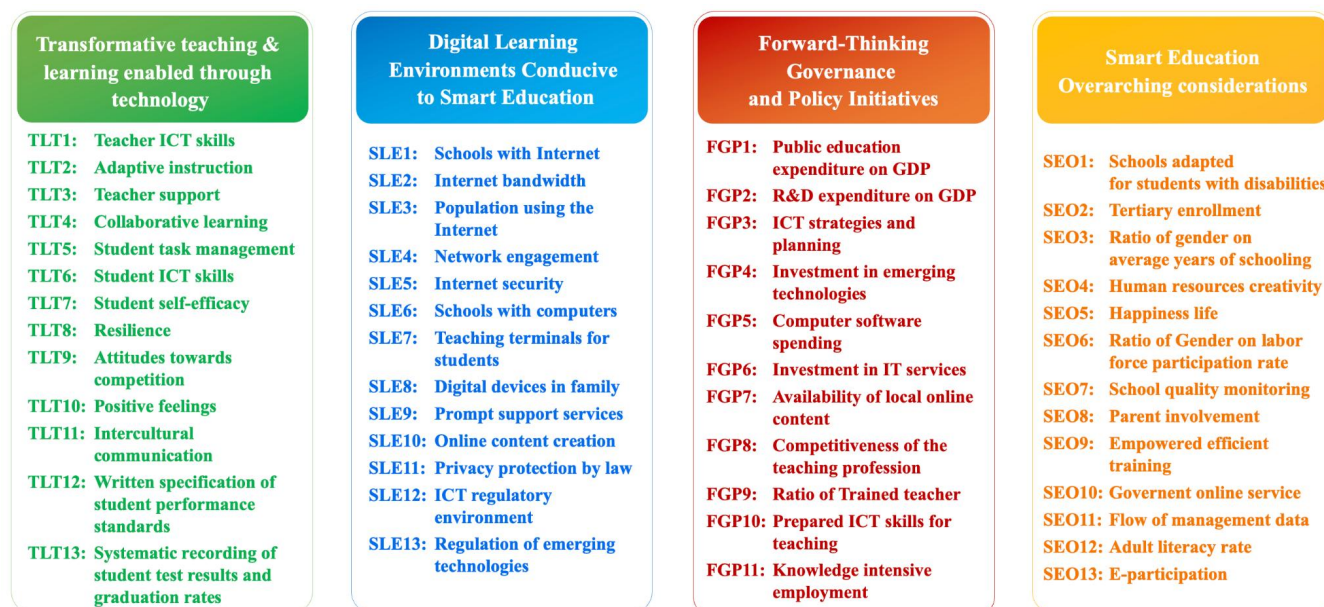
Transformative teaching & learning enabled through technology	Digital Learning Environments Conducive to Smart Education	Forward-Thinking Governance and Policy Initiatives	Smart Education Overarching considerations
TLT1: Teacher ICT skills TLT2: Adaptive instruction TLT3: Teacher support TLT4: Collaborative learning TLT5: Student task management TLT6: Student ICT skills TLT7: Student self-efficacy TLT8: Resilience TLT9: Attitudes towards competition TLT10: Positive feelings TLT11: Intercultural communication TLT12: Written specification of student performance standards TLT13: Systematic recording of student test results and graduation rates	SLE1: Schools with Internet SLE2: Internet bandwidth SLE3: Population using the Internet SLE4: Network engagement SLE5: Internet security SLE6: Schools with computers SLE7: Teaching terminals for students SLE8: Digital devices in family SLE9: Prompt support services SLE10: Online content creation SLE11: Privacy protection by law SLE12: ICT regulatory environment SLE13: Regulation of emerging technologies	FGP1: Public education expenditure on GDP FGP2: R&D expenditure on GDP FGP3: ICT strategies and planning FGP4: Investment in emerging technologies FGP5: Computer software spending FGP6: Investment in IT services FGP7: Availability of local online content FGP8: Competitiveness of the teaching profession FGP9: Ratio of Trained teacher FGP10: Prepared ICT skills for teaching FGP11: Knowledge intensive employment	SEO1: Schools adapted for students with disabilities SEO2: Tertiary enrollment SEO3: Ratio of gender on average years of schooling SEO4: Human resources creativity SEO5: Happiness life SEO6: Ratio of Gender on labor force participation rate SEO7: School quality monitoring SEO8: Parent involvement SEO9: Empowered efficient training SEO10: Governent online service SEO11: Flow of management data SEO12: Adult literacy rate SEO13: E-participation

Figure 9. Data Compilation Structure of Smart Education (50 indicators)

6.3 Smart Education Indicators′ Contribution

We formed a dataset from the National Educational Development Index, Digital Transformation of Society Indicators, Sustainable Development Indicators, Open Database for Education, Database of Teaching Quality, Teaching & Learning Indicators, and World Development Indicators.

First, we used the random forest method to select the top 25% of indicators with the highest contribution. Next, we analyzed the meaning of these important data metrics and combined indicators with similar meanings. Then, we employed expert consultation to identify indicators related to digital education. These confirmed indicators were matched with four leverages from the national smart education framework. Ultimately, we established a set of 50 indicators for data compilation structure of smart education.

Using the random forest method, we analyzed these 50 indicators to examine their contribution to PISA scores and SDG4 national benchmarks.

We selected the average performance of PISA's reading, mathematics, and science scores as the outcome variable from the OECD. The random forest model was used to determine the fit degree of the PISA results of the index data explaining the characteristics of smart education. More details in the figure 10.

A random forest model was employed to assess the alignment between PISA scores and index data related to smart education attributes. The four most influential indicators for PISA scores are SLE, followed by three FGP indicators.

The result indicates that it is vital to construct technology enriched environments for promoting student's learning outcomes, and the forward-thinking digital education policies serve as the guarantee for student's learning outcome.
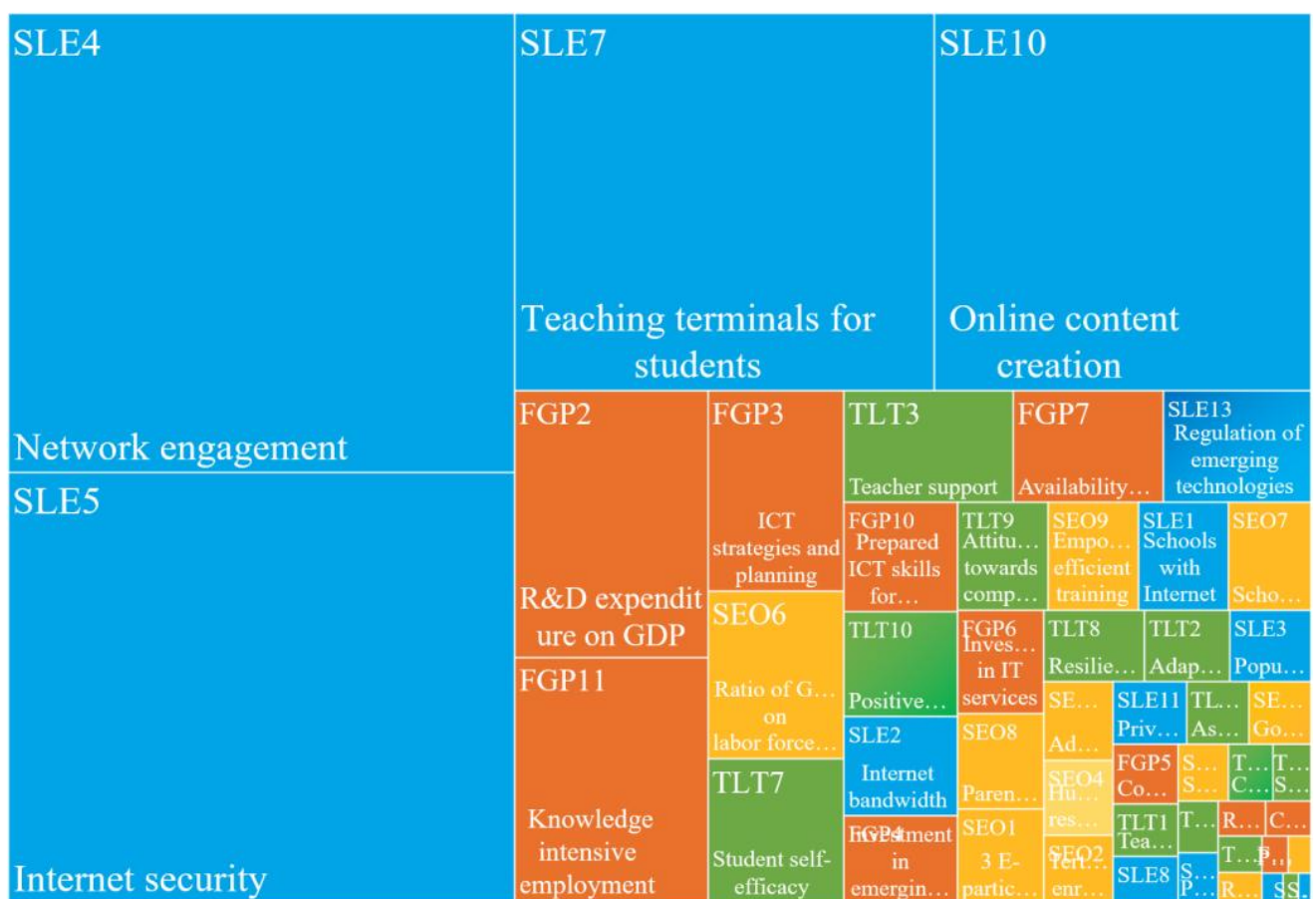

Figure 10. Smart Education Indicators' Contribution to PISA-Scores

We compiled the data on the seven indicators of SDG4 national benchmarks as the outcome variable. Using a random forest model to determine the degree of fitting of various indicator data explaining the characteristics of smart education to SDG 4 national benchmarks results in the Figure 11.

The three most influential indicators for SDG4 national benchmarks reflect SLE, SEO, and FGP. The result indicates that the three dimensions of SLE, SEO, FGP are the key to reach the goal of SDG4, therefore, it is of great importance to build SLE, put forward FGP, and pay attention to the SEO.
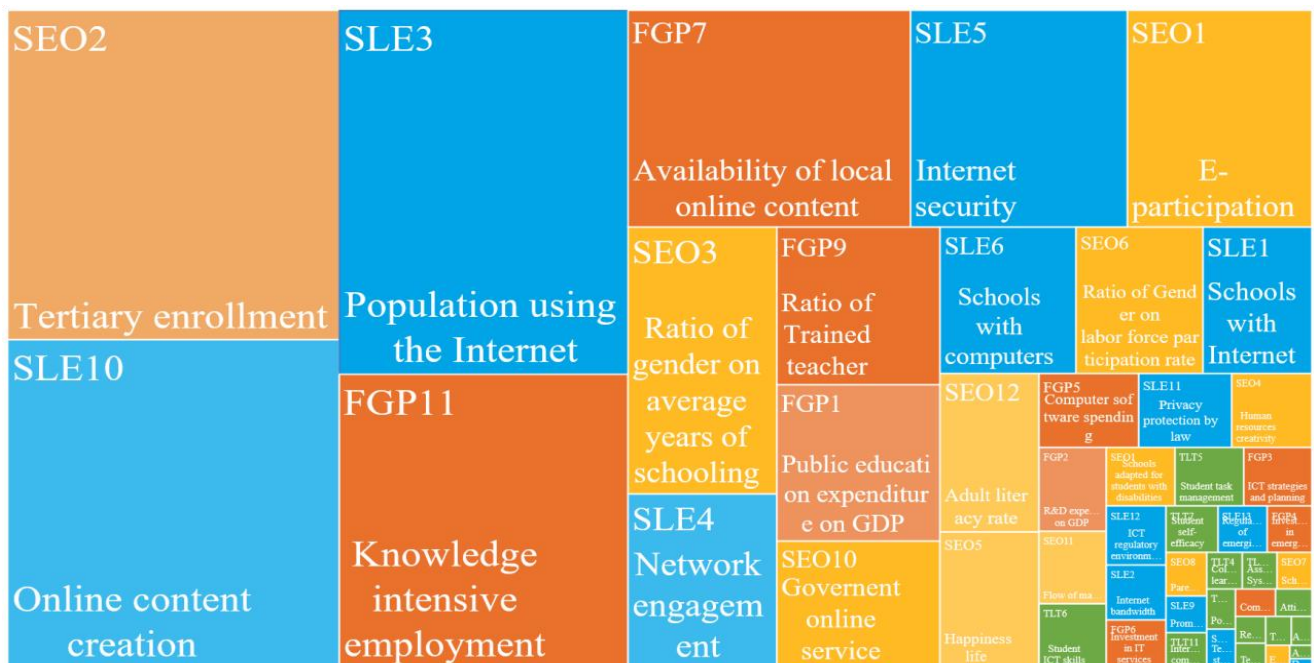

Figure 10. Smart Education Indicators' Contribution to PISA-Scores

7 Case of Educational Digital Transformtion towards Smart Education

The rapid advancement of technology has revolutionized education, transforming traditional learning into dynamic and interactive experiences. This section explores the cases of educational digital transformation towards smart education, highlighting key concepts, ideas, findings, and evidence. These cases showcase innovative approaches implemented in various countries. Notable examples include the implementation of smart learning spaces in the United Arab Emirates, the promotion of continuous improvement education culture in Argentina, China's commitment to equity in girls' education through digital technology, Morocco's sustainable plan for education reform, and Norway's effective multi-sector collaboration. These cases offer insights into leveraging technology to enhance education and create inclusive and engaging learning environments.

Smart and Ubiquitous Learning SPACES
Case1 United Arab Emirates: Higher Colleges of Technology, Ras Al Khaimah

This case study provides insights into the digital transformation in education at the Higher Colleges of Technology (HCT) in the United Arab Emirates (UAE). The interviewee shares information on the policies and initiatives implemented by HCT related to building smart and ubiquitous learning environments. HCT has implemented policies and initiatives to build a solid and mature ICT infrastructure, ensuring equity and equal chances to all staff members and students. Digital equipment, including internet, desktops, laptops, and printers, is available for students, teachers, and staff in HCT, and it is being utilized in various ways, including online delivery of courses and assessments.

Internet is accessible 100% for all HCT staff and students, and the university ensures equitable access to computers by providing school computers in all labs and allowing students to bring their own computers. Internet access is available in all HCT areas, including classrooms, common areas, faculty members, and staff offices. HCT has its own digital library, which is made available to all students and staff. Access to this library is integrated into the HCT portal, and it has a search engine embedded on it, allowing easy and quick access to all types of resources. HCT integrates technology into the curriculum and pedagogy by using Learning Management System (LMS) and various technology-based tools, including Kahoot, NearPod, Camtasia, and Google Teams, among others.

HCT also utilizes Blackboard as a Learning management system to integrate digital resources into teaching and learning. All course materials as well as gradebook are monitored and controlled through Blackboard. HCT ensures equitable access to digital resources for all students by providing a dedicated internet network where students can have full access to all the resources available in the school portal and the World Wide Web. The university provides professional development sessions and certifications to faculty members to keep them up-to-date with the new technologies that could be integrated in delivering their courses.

The UAE government has launched a national strategy to support innovation in education, including the Mohammed Bin Rashid Smart Learning Program, a joint venture between the Ministry of Education and the UAE Telecommunications Regulatory Authority in cooperation with the UAE Prime Minister's office. The initiative aims to create a solid and integrated Smart Learning initiative that actively involves teachers, students, and parents to enhance the learning experience. There are no ICT standards and policies, open educational resources regulations, or standards for creating digital resources and e-textbooks as well as using ICT in education at HCT. However, the Ministry of Education in the UAE provides a set of guidelines for schools, describing what students should know and be able to do in order to use creative design and technology effectively for learning and be prepared for university/college education as well as the job market.

Cultivating Continuous Improvement Culture

Case2　Ministry of Education of Argentina

The Ministry of Education of Argentina introduced the "National Integral Plan of Digital Education (PLANIED)" (MoEoA, 2017). In November 2017, outlining its mission and specific objectives. The mission revolves around integrating the educational community into digital culture. The plan's specific objectives include promoting digital literacy, fostering critical and creative use of Information and Communication Technologies, developing programming and computational thinking skills, encouraging participatory practices for responsible and supportive citizenship, strengthening educational institutions as drivers of knowledge in the digital society, and facilitating collaboration between students, teachers, schools, and communities through emerging communication and cultural practices. The study focuses on two key aspects: the "Pedagogical Guidelines of Digital Education" section, which aims to promote innovation in teaching and quality learning for comprehensive education, and the "Digital Educational Competence'' section, which emphasizes the incorporation of digital technologies as educational resources within an innovative framework known as digital education. The goal is to integrate teaching and learning processes into current and future cultural contexts to achieve meaningful educational outcomes.

Commitment to Inclusion and Equity in Education

Case3　China：Digital technology promote equity of girls′ education

Girls' education has always been the focus of extensive attention of the international community, and the use of information technology to empower girls and girls' education is of great significance in promoting the comprehensive development of girls. The case analyzes the current situation of girls' education in the era after the popularization of education in China and finds that Chinese girls are receiving digital education on an equal footing with boys.

It takes the construction of the "Internet+Education" demonstration area in Yuanzhou District, Ningxia as an example, and describes the typical cases of digital teaching practice of female teachers in Yuanzhou District, and analyzes in detail the process of girls' digital education. It also puts forward targeted suggestions to promote the cultivation of digital girls in line with the requirements of the times, with a view to providing reference for the study of girls' education and digital girls.

Background and Major Challenges . Yuanzhou District, located in Guyuan City, a mountainous area in southern Ningxia, was once a key area in China where girls' education faced great difficulties. By 2020, Yuanzhou District has achieved full coverage of school-age girls' education. However, from a nationwide perspective, Yuanzhou is still a relatively weak area in China's education quality development.Generally speaking, girls' education in ethnic minority areas lags behind seriously, and problems such as low enrolment rate, high dropout rate and poor cultural quality of girls are very prominent.Teachers are one of the most important factors influencing student learning and need opportunities for professional development, education, and support to work with a diverse group of people who are ethnically, culturally and linguistically diverse in order to be able to accommodate and adequately assist those with special needs.

Major initiatives to promote digital literacy in Yuanzhou District. With the deepening of information technology applications in Yuanzhou District,the internal and external environments of education that affect girls' enrolment and access to high-quality education have been fundamentally improved.

Sustainable Plan for Education Reform

Case 4   Morocco：Center of Educational Guidance and Planning, Rabat

This case provides an overview of the aspects of digital transformation in education in the Center of Educational Guidance and Planning, Rabat, Morocco. The interviewee, who is a professor affiliated with the center, discusses various policies and initiatives that have been implemented to build an ICT infrastructure and integrate technology into teaching and learning.

The Moroccan government has launched a national strategy to equip schools with technological equipment and multimedia classrooms, known as the Generalization of Information and Communication Technology in Education. As part of this strategy, more than 11,000 schools have been connected to the internet, and each school has Multimedia classrooms. The government has also developed a national e-learning platform for teachers and students to access free digital resources.

To ensure equitable access to digital resources, all students have a private digital space that can be accessed using their own account, which contains information about lessons, grades, guidance, and digital resources. The Ministry of Education has also developed an ICT guide to help teachers use digital resources in their pedagogical practices.Despite these initiatives, challenges remain in integrating technology into teaching and learning, including the cost of digital equipment and the need for teacher training and support. The Ministry of Education is addressing these challenges by building programs for school equipment and training teachers.

The government has launched a national program for developing the uses of information and communication technology in education to develop the competencies of learners and improve the professional performance of teachers. The government has also developed a big digital system called ''MASSAR system''. Additionally, the government has established a national committee to promote digitalization in education, which oversees the strategy.

The Moroccan educational system has also developed editorial LMS to produce educational practices by teachers and different platforms of open educational resources (OER) to support students and teachers in their teaching and learning. The system is starting to develop standards for creating digital resources and e-textbooks as well as using ICT in education.

Effective Multi-Sector Collaboration

Case 5   Norway

Norway's Ministry of Education and Research introduced the "Digitalization strategy for basic education 2017-2021" (Norwegian Ministry of Education and Research, 2017) in August 2017, with a focus on differentiated teaching, educational equality, and the digital advancement of education through effective collaboration among multiple stakeholders. The strategy highlights the importance of cross-departmental collaboration, including the involvement of colleges, student councils, and Parent-Teacher Associations (PTAs) in developing ICT plans to facilitate the digital development of schools. Municipalities and county councils work in collaboration with students and staff to ensure a strong ICT architecture and the procurement of digital teaching aids, equipment, systems, and infrastructure that align with the municipality's educational objectives. Additionally, cooperation with the labor market aims to enhance vocational education and training to adapt to the changes brought about by new technologies. Professional boards and social partners are also involved in updating the content of vocational education and training programs. Norway recognizes the significance of collaboration across departments, school-municipality partnerships, and engagement with the labor market to foster a comprehensive and effective digital education ecosystem.

Conclusions

The report delves into the topic of smart education within the ongoing technology-in-education debate, advocating for a balanced perspective. It defines key traits of smart education, such as personalization and interactive learning. The report highlights student-centered teaching, comprehensive assessment, smart learning environments, continuous improvement, inclusivity, and other essential aspects. Constructive facets of smart education emphasize fostering social learning communities, supporting educators, promoting ethical technology adoption, implementing sustainable reforms, and facilitating effective collaboration.

In summary, key features of smart education in terms of both education and technology attributes are identified to respond to the debate on the efficiency of technology in education.

The digital education policy analysis indicates two issues

- Policies in different countries reflect different stages of digitization, digitization, digital transformation
- There are some common characteristics in the four dimensions of smart education within each specific stage.

The most influential indicators through global data analysis

- The result indicates that all four dimensions contribute to the quality of education in terms of PISA-Scores.
- It is vital to construct technology enriched environments for promoting student's learning outcomes, and the forward-thinking digital education policies serve as the guarantee for student's learning outcome..
- The result indicates that the three dimensions of SLE, SEO, FGP are the key to reach the goal of SDG4.
- It is of great importance to building SLEs, put forward FGP, and the pay attention to the SEO.

Implications

- Key features of smart education in terms of both education and technology attributes are identified to response the debate on the efficiency of technology in education.

- The key features of smart education help to make the NSE framework practical and contributes to achieving sustainable policies and smart learning environments.

- The digital education policy analysis indicates: policies in different countries reflect different stages of digitization, digitization, digital transformation, and there are some common characteristics in the four dimensions of smart education within each specific stage.

- Random forest algorithm with global public dataset show that the four components TLT, SLE, FGP and SEO are all contributed to OECD PISA Scores, but less importance of TLT be found to SDG4 benchmarks, so national strategies on smart education which involve technology empowered learning and teaching will be crucial.

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