

# Embracing the Trend of Educational Digitalization to Enhance the Quality and Effectiveness of Basic Mathematics Teaching

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**Abstract** Educational digitalization is a trend in both domestic and international educational development. The importance of educational digitalization lies in its potential to improve the efficiency, engagement, and equity of education. However, it also encounters challenges in terms of macro-planning, support infrastructure, and regional balance, which necessitate proactive responses. As a crucial contributor to the process of educational digitalization, the community of educators, notably those teaching foundational mathematics, must adapt to the evolving landscape. By shifting their mindsets, enhancing their capabilities, and guiding students accordingly, they can effectively enhance the quality and effectiveness of teaching, thereby making substantial contributions to the advancement of educational digitalization.

**Keywords** educational digitalization, impact assessment, adaptation strategies, technological progress

## 1 Introduction

Amidst the ongoing technological advancements, educational digitalization has emerged as a prevailing trend and an inevitable trajectory within the realm of education (Chen et al., 2023). Foundational mathematics education, as a fundamental discipline, is not exempt from the influence of educational digitalization. It is imperative to actively embrace this shift, adapting and formulating responsive strategies accordingly, and seizing the opportunities that arise amidst the transformative developments brought about by educational digitalization.

### 1.1 | Evolution of Educational Digitalization

A comprehensive understanding of the digitalization of foundational mathematics education necessitates an initial comprehension of the broader context of educational digitalization. In a narrow sense, the process of educational digitalization involves the integration of digital technologies into all stages of teaching—preparation, implementation, and feedback. In a broad sense, it encompasses the digitalization of the entire educational ecosystem, including its physical and virtual environment, pedagogical methodologies, and assessment frameworks (Dou & Xu, 2023). This transformative endeavor revolutionizes education on multiple fronts. Globally, efforts are being made to seize the opportunities presented by technological progress and adapt to the tide of digitalization, aiming to propel the digital transformation of education by deeply integrating education with technologies—shaping education through digital mediums.

### 1.2 | International Development

To align with the trajectory of educational digitalization, numerous countries, regions, and international organizations are actively advocating for the advancement of educational digitalization through enhanced awareness and strategic planning. Research conducted by Wu et al. (2023) and Wu et al. (2022) indicates that 14 major countries across 6 continents, namely North America, South America, Asia, Europe, Africa, and Oceania, as well as significant international organizations such as the United Nations and the European Union, have established plans and strategies for the development of educational digitalization. The promotion of educational digitalization has garnered international consensus.

The United States views educational digitalization as a critical approach for enhancing the nation's

educational benchmarks. The objectives of educational digitalization encompass the promotion of full employment, expediting cultivation of digital talent to meet future market demands, and addressing structural labor shortages. Furthermore, it strives to advance educational equity. As early as the Obama administration, educational digitalization served as a pivotal mechanism to progress educational disparities. The president, Biden, has embraced the concept of educational digitalization and is driving its implementation through policy initiatives such as the *Digital Equity Plan* and efforts to eliminate the digital divide. In terms of specific implementation, the United States is actively advocating for the transformation of educational digitalization by continuously enhancing hardware and software infrastructure, augmenting the digital technology capabilities of teachers, bolstering digital literacy of students, thereby comprehensively reinforcing the nation's educational digital ecosystem.

In Germany, digitalization is recognized as a pivotal component of the education system, with a focus on enhancing the overall digital capabilities of the population (Zhou, 2023). As early as 2014, Germany initiated the *Digital Strategy 2025* (Federal Ministry for Economic Affairs and Energy of Germany, 2016), which outlined comprehensive plans for educational digitalization and delineated the tasks for the progressive development of digital infrastructure at different educational stages. This was succeeded in 2016 by unveiling the *Offensive for Digital Knowledge-Based Society*, published by the German Federal Ministry of Education and Research (BMBF) (German Federal Ministry of Education and Research, 2016). The strategy establishes goals for the development of educational digitalization to be accomplished by 2030. To attain these objectives, Germany has implemented diverse measures tailored for different educational groups. For instance, in primary and secondary education, the emphasis is on upgrading educational digitalization infrastructure and cultivating conducive digital media environment. In terms of investment in educational digitalization, a collaborative model involving federal and state governments has been adopted to optimally address the human resources and material requirements for educational digitalization. Prioritizing the establishment of an exemplary digital education system, encompassing software and hardware components, as well as formulating a rigorous standardization framework for educational digitalization, are paramount.

In Japan, the proactive promotion of educational digitalization is a salient feature of contemporary policy (Duan & Ruan, 2023). In 2019, the country officially enacted the *Act for Promoting the Informatization of School Education* (Ministry of Education, Culture, Sports, Science and Technology of

Japan, 2019a) and initiated the *Global and Innovation Gateway for All (GIGA)* (Ministry of Education, Culture, Sports, Science and Technology of Japan, 2019b), aimed at providing every student with a digital device by establishing a high-speed campus communication network to accommodate online teaching requirements during the COVID-19 pandemic. The objective is to address current deficiency in digital literacy at Japan's compulsory education stage, thereby enhancing the equity and efficacy of this foundational education phase. To ensure the realization of GIGA initiative, Japan has employed three strategies: first, financial backing from both central and municipal governments to ensure resources; second, infrastructure support by strengthening the supply of high-quality digital learning resources and optimizing online teaching systems; third, teacher support by enhancing their digital capabilities and improving their abilities to teach effectively in digital domains. Through the implementation of the GIGA initiative, Japan's educational digitalization has made significant progress.

### 1.3 | Domestic Development

Throughout its history, China has placed significant emphasis on the development of education. China's pursuit of educational digitalization dates back to the commencement of the reform and opening-up policy and has persisted to the present day (Chen & Kong, 2023). The country has consistently endeavored to explore the progression of educational digitalization.

During the initial phases of the reform and opening-up policy, China introduced the concept of electronic education, which could be considered as the rudimentary stage of educational digitalization. In 1978, the National Center for Educational Technology was founded, and subsequently, electronic education departments were established in several universities, such as South China Normal University. This signified the commencement of educational informatization in China.

In the new century, the national objectives and strategies for advancing educational informatization became more defined. In 2012, the Ministry of Education (MOE) of the People's Republic of China introduced the *Ten-Year Plan for Education Informatization (2011–2020)* (Ministry of Education of the People's Republic of China, 2012), which sought to establish an educational informatization system aligned with the national objectives of educational modernization by 2020.

Since 2012, China's focus has gradually shifted from educational informatization to educational digitalization. In 2018, the MOE unveiled the *Education Informatization 2.0 Action Plan*, outlining basic goals to achieve "widespread use of teaching applications for all

educators, learning applications for all school-aged students, and digital campus construction for all schools by 2022, alongside enhanced levels of information application and literacy among educators and students” (Ministry of Education of the People’s Republic of China, 2018). The aim of the plan was to continuously advance the deep integration of information technology and education, simultaneously enhancing both aspects (Ministry of Education of the People’s Republic of China, 2018).

In 2019, the Central Committee of the Communist Party of China (CPC) and the State Council jointly issued *China’s Education Modernization 2035* (Central Committee of the Communist Party of China & The State Council of the People’s Republic of China, 2019), emphasizing the need to accelerate educational transformation in the information age and establish a mechanism for co-construction and sharing of digital educational resources. In *The Outline of the 14th Five-Year Plan (2021–2025) for National Economic and Social Development and Vision 2035 of the People’s Republic of China* announced in 2021 (The State Council of the People’s Republic of China, 2021), emphasized to promote digital service accessibility and continually enhance the public satisfaction in education. Educational digitalization was positioned as an integral component of China’s overall digital development.

## 2 Positive Role of Educational Digitalization

Educational digitalization, as a global trend in educational development and a national strategic initiative, plays a comprehensive and profound role in advancing education. It encompasses various aspects such as integrating the five dimensions of education—purpose, student engagement, curriculum and pedagogy, assessment for student learning, and classroom environment and culture—creating new learning environment, and facilitating high-quality development (Li, 2023). Its impact on foundational mathematics education should not be underestimated, as it serves as an important means to enhance the quality and effectiveness of teaching. Overall, educational digitalization contributes to the promotion of educational development in numerous ways, including efficiency, interest, and fairness.

Firstly, educational digitalization enhances *efficiency*. Sustained financial investment is crucial for promoting educational progress in the long run. Educational digitalization requires a certain level of investment to ensure the basic supply of infrastructure and human resources. Yet, the iterative upgrading of

educational models brought about by educational digitalization can effectively enhance the efficiency of deployed educational resources (Ren & Li, 2024). The traditional classroom characterized by large student populations, inherently diminishes teaching efficiency since it is challenging for teachers to cater to each student’s personalized needs. Initially, this problem may not be urgent. Nonetheless, as economic and social development continues to advance and people’s demands for high-quality education increases, the inefficiencies arising from this phenomenon becomes more apparent. The persistence of a non-individualized and multi-student classroom arrangement necessitates the intervention of educational digitalization as a viable corrective measure. For example, if each student has access to digital terminals, teachers can assign customized mathematics exercises both during and after class. Therefore, educational digitalization optimize deployment of educational resources, augmenting efficiency without increasing teacher resources.

Secondly, educational digitalization enhances *interest*. The cultivation of educational interest is an enduring objective in education, particularly in the context of foundational disciplines. During the primary and secondary school stages, as students’ minds gradually mature, it is pivotal to instill a love for learning and ignite their interest. One notable advantage of educational digitalization is its capability to present various types of digital resources transcending temporal, geographical, and genetic boundaries, stimulating students senses, sparking their imagination, aiding comprehension, and enhancing intrinsic motivation (Xu et al., 2023a). For instance, in the fundamental mathematics education, “circle cutting” is a captivating topic that demands imagination. However, it is challenging to vividly explain using traditional teaching tools, such as blackboards and chalk. Digital devices empowers educators to manipulate visual representations dynamically, magnifying circles to a point where their curvature approximates straight lines, a feat challenging to achieve with traditional methodologies. Harnessing digital technology can readily address this issue, enabling students not only to comprehend the concept of “circle cutting,” but also to grasp more advanced mathematical concepts related to integration.

Thirdly, it promotes *fairness* (Xu et al., 2023b). This fairness can be viewed from two levels, the micro level and macro level. Firstly, at the *micro level*, classroom dynamics underscore the importance of fairness among students. Different students exhibit varying feedback mechanisms in response to instructional approaches. While some students actively provide feedback and promptly raise questions when they encounter difficulties, others may be more passive and struggle to express uncertainties. Consequently, the

same teacher, intentionally or unconsciously, tends to consider the needs of students who provide positive feedback more frequently. Students who offer negative feedback, despite ostensibly receiving the same education, actually have reduced opportunities for learning. Educational digitalization can partially address this issue in the foundational mathematics education context. Teachers can objectively assess students' performance in digital exercises during class, enabling students to promptly adjust pedagogical strategies. Meanwhile, real-time analysis of digital exercise outcomes empowers educators to timely clarify and assist students who are hesitant to voice their misunderstandings. Secondly, fairness at the *macro level* extends to different regions, urban and rural areas, and schools. The substantial differences in instructional quality across different regions and schools pose a formidable challenge to equitable education. Addressing this problem necessitates the efficacious allocation and dissemination of educational resources. Educational digitalization emerges as a potent catalyst in this endeavor, facilitating the seamless sharing and transfer of high-quality educational content through online classrooms, synchronous online teaching, and dual-teacher instruction. These innovations democratize access to high-quality educational resources, thereby serving as instrumental in enhancing educational equity.

### 3 Challenges of Educational Digitalization

Building a high-level digital education system requires continuous efforts. Although China has made significant progress in promoting education digitalization, three major challenges still need to be overcome, including the macro-level planning, ensuring support, and regional balance.

The first challenge lies in *macro-level planning* for educational digitalization. Given its expansive scope, encompassing both direct and ancillary aspects of the educational landscape, the absence of a macro-level scientific planning, and a clear top-level design impedes systematic progress. Strengthening macro-level planning necessitates systematic considerations of key issues such as ideology awareness, integration harmoniousness, and infrastructure robustness. Firstly, it requires unified *ideology awareness*. Educational digitalization, as a contemporary phenomenon, encounters divergent interpretations among teachers, parents, students, and other stakeholders (Shang & Li, 2023). To remove ideological barriers that hinder the advancement of digitalization, it is crucial to enhance publicity and guide societal consensus towards

promoting educational digitalization. Secondly, the *integration* harmoniousness with digital economy should be considered. Educational digitalization is an integral part of building a digital China and should be advanced in tandem with the development of a digital economy (Zhang, 2023). Isolated pursuits of digitalization within education would not align with the concept of digital China. Thirdly, from the perspective of educational digitalization itself, a substantial amount of *infrastructure robustness* is required. At the national level, the construction of standard systems should be contemplated to enhance hardware compatibility and software adaptability, thereby avoiding wastage of resources resulting from each region or unit acting independently.

The second challenge pertains to *ensuring support*. Educational digitalization involves significant investments in infrastructure and human resources, mandating fortified organizational support. At the national level, the formation of high-level bodies for coordination and decision-making is necessary to provide visible support and impetus for the overall advancement of educational digitalization. Adequate funding must be secured as well. Educational digitalization involves both central and local authorities, requiring the full mobilization of proactive efforts at both levels to strengthen financial coordination among different hierarchies, including central, provincial, municipal, and county levels, to ensure sufficient and sustainable financial support for educational digitalization. Notably, the strategic action plan is implemented by the Ningxia Hui Autonomous Region at the provincial level, which exemplifies effective resources consolidation within the region to support educational digitalization.

The third challenge concerns *regional balance* in educational digitalization. Ideally, this process should serve as an effective means to bridge educational inequalities rather than exacerbating them. In the face of current disparities between regions and urban-rural areas, as well as the necessary financial and technological investments for educational digitalization, reinforcing national-level coordination is essential. Otherwise, the advancement of educational digitalization may not achieve the desired fairness and may even intensify regional and urban-rural disparities. The *Research Report on the Digital Transformation of Chinese Primary and Secondary Education* reveals significant differences in the degree of educational digitalization between eastern and western regions of China (China National Academy of Educational Sciences & Chinese Society of Educational Development Strategy, 2023). Measures should be introduced at the national level to encourage pilot projects in areas where conditions permit, while also strengthening support and assistance between regions and schools

through mechanisms such as financial transfers and targeted assistance. These measures aim to promote balanced development in educational digitalization as much as possible.

## 4 Role of Educators in Educational Digitalization

Educators are crucial driving force towards educational digitalization. Rather than adopting a passive stance or resisting change, they ought to embrace proactive roles as participants, contributors, and leaders in this transformative process. This also applies to the field of foundational mathematics education, where teachers should start their engagement by improving the quality and effectiveness of mathematics teaching, in order to demonstrate their role in educational digitalization. In conclusion, to catalyze the educational digitalization, educators should cultivate mindset, develop digital literacy, provide student guidance, and provide collaborative participation.

Firstly, a change in *mindset* is crucial. Educators should deeply understand that educational digitalization is not only an inevitable result of technological progress, but also a direction for promoting the development of world education. Teachers, as an essential part in education, need to be equipped with the mindset of digital literacy, aligning themselves with this unstoppable tide. Currently, although many teachers use digital tools in their teaching, some teachers still have misunderstandings. For example, some people believe that the traditional “chalkboard” teaching model is effective and resist the use of digital devices and technologies. Others mistakenly believe that educational digitalization is superficial and incapable of truly enhancing teaching quality, demonstrating resistance to digitalization. As key contributors to promoting educational digitalization, educators must collectively form consensus and take action, actively consider how to plan, promote, and improve educational digitalization, assist the country in strengthening macro-planning and top-level design. Moreover, contributors ought to seize the mantle of innovation exploring pioneering opportunities in the process of educational digitalization.

Secondly, teachers should enhance their *digital literacy* for efficient teaching and learning. On one hand, government and educational institutions should provide teachers with user-friendly digital hardware and software for teaching purposes, accompanied by robust support systems for educational digitalization. On the other hand, teachers themselves should take the initiative to learn the teaching skills required for

educational digitalization. By enhancing their proficiency in digital technologies, mastering various digital software and devices, teachers can enhance their digital literacy in education. While there may still be a gap between the current level of support for educational digitalization and actual development needs, teachers can actively and broadly utilize and integrate digital resources to enrich their teaching before there is widespread access to vast digital resources and effective communication channels between students and resources. The ultimate goal of digitalization is to provide personalized teaching to ensure that every student receives the best teaching and growth. This requires teachers to give every student the fullest care, without any bias. Therefore, the most important thing is that teachers must have the mindset of “educating without discrimination” and “treating every student fairly”. In addition, teaching resource allocation can be optimized by combining on-campus and off-campus, online and offline, and internal and external digital systems to meet the diverse needs of teachers and students, thus fully leveraging the role of digitalization.

Thirdly, *student guidance* must be strengthened. Students are the beneficiaries, targets, and protected individuals in the process of educational digitalization. The educational digitalization presents safety concerns (Ma, 2023). For students, especially those in primary and secondary schools, who are in a critical period of mental development, precautions must be taken to prevent physiological harm caused by excessive exposure to digital products and psychological harm caused by harmful digital information (Wen, 2021). Therefore, teachers must prioritize the safety aspect of educational digitalization and cultivate good habits in students regarding scientific and reasonable use of digital products and information. At the same time, educators should not be overly cautious. As students mature, it is important to provide them with opportunities to actively engage with digital products and develop their independent learning abilities in a digital environment. For instance, in the context of fundamental mathematics education, teachers can record short pre-class videos on mathematical topics for students to preview. They can also use question–answer applications to provide practice exercises tailored to different difficulty levels and students’ mastery levels, allowing students to assess their learning progress. By employing scientific and controllable methods, teachers can help students reap the benefits of educational digitalization.

Fourthly, *collaborative participation* should be emphasized. Educational digitalization combines moral, intellectual, physical, aesthetic, and labor education. It is also a digitalization that benefits the governments, societies, schools, teachers, and students, necessitating the active engagement of all stakeholders in this

multidimensional process. Promoting educational equity is an enduring topic and a practical challenge in educational digitalization (Wang et al., 2023). Solving the issue of regional imbalances in educational digitalization requires concerted efforts from the government and society as a whole. However, individual teachers can also contribute to the cause by consolidating the collective strength of equalizing educational opportunities through their own actions. In addition to traditional forms of educational support, in today's highly developed and widely accessible internet era, teachers can publish high-quality video lessons, create virtual-reality courses, and offer free online tutoring sessions on educational platforms, providing digital resources that benefit regions and schools with relatively limited access to educational quality.

**Conflict of Interest** The authors declare that they have no conflict of interest.

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