Research on Educational Transformation and the Adaptability of Digital Pedagogy from the Perspective of Digital Natives

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Abstract:
Against the backdrop of digital technologies profoundly reshaping society, the unique cognitive characteristics of digital natives pose challenges to traditional educational models. This study, grounded in constructivist learning theory and the Technology Enhanced Learning (TEL) framework, systematically analyzes the cognitive traits of digital natives in areas such as fragmented information acquisition, visual learning preferences, and collaborative knowledge construction. Through case studies and empirical analysis, it proposes that digital pedagogy must adapt through four dimensions: integrating fragmented instructional content, designing multimodal interactions, implementing AI-adaptive learning pathways, and creating blended virtual-physical teaching environments. Findings confirm that adapted digital pedagogy enhances digital natives' learning engagement and knowledge internalization efficiency, providing theoretical foundations and practical pathways for educational digital transformation.

Keywords: cognitive adaptation; blended learning; digital natives; digital pedagogy; educational transformation

1. Introduction

Digital technology has been transforming contemporary society at an unprecedented scale and speed. As a central driver of modern development, digital innovation has reshaped economic activities, social interactions, and educational practices. The digitalization of communication, the expansion of online platforms, and the rapid advancement of information technologies have significantly altered how individuals access information, construct knowledge, and engage with learning environments. In the educational domain, digital technology has enabled new instructional models, expanded access to learning resources, and facilitated more flexible learning experiences beyond traditional classroom boundaries.

Within this rapidly evolving digital landscape, the emergence of the so-called *digital natives* has attracted considerable scholarly attention. The term *digital natives*, introduced by Marc Prensky in 2001, refers to a generation that has grown up surrounded by digital technologies such as the internet, smartphones, and social media. Unlike earlier generations who had to adapt to digital technologies later in life, digital natives have been immersed in these technologies since childhood. As a result, digital technology forms an integral part of their daily experiences and cognitive processes. For digital natives, digital environments are not merely tools for communication or learning but natural extensions of their social and intellectual activities.

The pervasive influence of digital technologies has shaped distinctive cognitive and behavioral patterns among digital natives. They tend to process information rapidly, engage in multitasking, and prefer multimodal learning environments that combine text, images, audio, and video. Visual content and interactive media often play a crucial role in their knowledge acquisition processes. Furthermore, digital natives frequently rely on collaborative learning practices facilitated by online platforms, where knowledge is constructed collectively through digital communication and shared resources. These characteristics indicate that digital natives often adopt more dynamic, interactive, and technology-mediated learning approaches.

However, these emerging cognitive and learning characteristics present significant challenges to traditional educational models. Conventional education systems, largely rooted in industrial-era pedagogical paradigms, tend to emphasize linear knowledge transmission, teacher-centered instruction, and standardized learning processes. Such approaches may not fully correspond to the learning preferences and cognitive styles of digital natives. Consequently, there is increasing recognition that educational systems must undergo structural transformation to accommodate the changing needs of learners in the digital era.

Scholarly research on digital natives has developed extensively over the past two decades. Early discussions following Prensky's conceptualization stimulated debates regarding the extent to which digital natives differ from previous generations in their digital competencies and learning styles. Subsequent studies have questioned the assumption that all individuals born in the digital age possess advanced digital skills. For example, research by Sue Bennett, Karl Maton, and Lisa Kervin emphasizes that digital proficiency varies considerably among individuals and should not be assumed solely on the basis of generational identity. Empirical investigations have also demonstrated that social environment, educational opportunities, and digital access significantly influence digital literacy development.

Recent research has increasingly focused on the implications of digital transformation for educational practice. Digital technologies have enabled innovative pedagogical models, including personalized learning, blended learning, and collaborative learning environments. Studies suggest that technologies such as big data analytics and artificial intelligence can support adaptive learning systems capable of addressing individual learning needs. Within this context, digital pedagogy has emerged as an important framework for understanding how educational practices can be redesigned to effectively integrate digital technologies into teaching and learning processes. Notably, the digital pedagogy framework proposed by Huang Ronghuai highlights several critical dimensions of educational transformation, including technology-enabled deep learning, sustainable digital learning environments, evidence-based instructional practices, and human–machine collaborative learning.

Despite the growing body of literature on both digital natives and digital pedagogy, an important gap remains in understanding the relationship between these two areas. Much of the existing research examines either the characteristics of digital natives or the application of digital pedagogy in isolation. Relatively limited attention has been given to exploring how digital pedagogical approaches can be systematically designed to align with the cognitive characteristics and learning preferences of digital natives. In particular, there is a lack of comprehensive empirical studies examining how digital pedagogy can accommodate features such as fragmented information processing, visual learning preferences, and collaborative knowledge construction.

Addressing this gap is essential for the future development of education in the digital age. The effectiveness of digital pedagogy depends not only on technological integration but also on its compatibility with the cognitive patterns and learning behaviors of contemporary learners. Therefore, this study seeks to investigate how digital pedagogical approaches can be optimized to better align with the cognitive characteristics of digital natives. Specifically, this research explores the cognitive dimensions of digital natives in terms of information acquisition, learning preferences, and knowledge construction, and examines how digital pedagogy can be designed and implemented to support these characteristics in educational practice. By providing both theoretical insights and practical implications, this study aims to contribute to the ongoing transformation of education in the digital era.

3. Research Methodology

Research Design

This study employs a mixed-methods approach, integrating quantitative and qualitative research to comprehensively explore the adaptability of educational transformation to digital pedagogy. This methodology leverages the objectivity of quantitative research and the depth of qualitative inquiry, gathering data from multiple perspectives to reveal the research questions thoroughly and incisively.

Case studies were employed to select representative schools and courses, enabling an in-depth analysis of how digital pedagogy is applied in actual teaching contexts. Detailed documentation of teaching processes, student learning outcomes, and adjustments to teaching strategies vividly illustrates the implementation effectiveness and challenges of digital pedagogy across diverse instructional settings. Concurrently, a longitudinal study tracks project-based learning practices to observe student

collaboration methods, knowledge construction processes, and digital tool utilization during project implementation.

Empirical analysis will validate hypotheses regarding the compatibility between digital teaching methods and the cognitive characteristics of digital natives through large-scale surveys and data analysis. Statistical methods will quantify collected data to derive generalizable and reliable conclusions. Surveys targeting digital natives' learning traits and the effectiveness of digital teaching methods will gather student and teacher data, analyzing how different digital teaching approaches impact student academic performance, learning interest, and engagement.

Data Collection

a. Questionnaire Survey

A questionnaire was designed for digital native students, covering their information-seeking habits, learning preferences, acceptance of digital teaching methods, and satisfaction levels. The questionnaire was distributed through a combination of online and offline methods to ensure broad sample coverage and representativeness. Online platforms like Wenshu Xing facilitated efficient data collection. Offline distribution occurred across diverse schools and educational institutions, covering students from different regions and levels. Multiple primary/secondary schools and universities in urban and rural areas were selected. Students were sampled proportionally, with 1,000 questionnaires distributed and 850 valid responses collected.

b. In-Depth Interviews

Teachers with extensive teaching experience and active involvement in digital teaching practices were selected for interviews. Discussions centered on core topics including teachers' perceptions of digital native students' characteristics, digital teaching methods employed in instruction, encountered challenges and improvement suggestions, as well as students' experiences and needs regarding digital teaching. Semi-structured interviews were employed to allow teachers ample space to express their views while ensuring discussions remained focused on the research themes. Through face-to-face, telephone, or video interviews, a total of 20 teachers and 40 students from different educational levels were interviewed. Detailed records of the interviews were kept, providing rich qualitative data for subsequent analysis.

Case Studies

Select representative cases of digital teaching methods, such as an immersive teaching course utilizing virtual reality technology at a university or a personalized learning program based on big data analysis implemented at a secondary school. Conduct on-site visits to collect relevant teaching materials, including instructional design documents, student work, classroom recordings, and teaching reflections. Analyze these materials to identify the strengths, challenges, and areas for improvement in the practical application of digital teaching methods.

Data Analysis

Process questionnaire data using statistical analysis software SPSS. Begin with data cleaning to verify completeness and accuracy, removing invalid entries. Conduct descriptive statistical analysis to calculate means, standard deviations, frequencies, and other metrics, establishing baseline characteristics of digital native students across domains. Subsequently, correlation analysis, factor analysis, and ANOVA were employed to investigate the relationship between digital pedagogy and the cognitive characteristics of digital natives, analyzing the impact of various factors on student learning outcomes. For qualitative data collected from teacher interviews and case studies, thematic analysis was applied. This involved reading and coding interview transcripts and case materials sentence by sentence, decomposing textual content into multiple units of meaning and assigning a code to each unit. Codes were then categorized and synthesized, merging related codes into themes to further distill core themes and subthemes. This thematic analysis provided deep insights into teachers' perceptions and practical experiences with digital pedagogy, as well as its specific manifestations and outcomes in real-world applications. Key themes extracted from teacher interviews included the strengths of digital pedagogy in fostering collaborative and personalized learning, alongside challenges in technology implementation and instructional management.

4. Findings and Discussion

Cognitive Characteristics of Digital Natives

As a cohort raised alongside iterative digital technology advancements, digital natives' cognitive patterns have developed distinct characteristics shaped by immersion in digital environments. These traits fundamentally reshape their learning behavior logic and form the core basis for educational transformation and digital pedagogy adaptation. This section systematically analyzes digital natives' core characteristics in information acquisition, learning preferences, and knowledge construction based on questionnaire surveys, in-depth interviews, and teaching case studies.

a. Information Acquisition: Fragmented, Search-Based Learning

Digital natives exhibit highly fragmented information-seeking behaviors characterized by "high frequency, short duration, multiple sources, and scattered points." This aligns closely with the immediacy and fluidity of information dissemination in the digital age. Survey results indicate that 83.7% of digital native students access information via mobile smart devices (phones, tablets, etc.) more than five times daily. Each session typically lasts 5-15 minutes, with 41.2% of students spending no more than 10 minutes per session. This "squeezing in" approach to information consumption enables them to maximize fragmented time for accessing vast amounts of information, forming a closed-loop information processing cycle of "immediate need – rapid retrieval – instant feedback."

Regarding information acquisition methods, digital natives exhibit strong "search dependency." When encountering academic challenges, 76.2% of students first turn to search engines like Baidu or CNKI Research to find solutions, bypassing traditional approaches such as consulting textbooks or seeking teacher guidance. Their information sources exhibit high dispersion. Survey data reveals the following descending order of daily learning information sources: short video platforms (e.g., Douyin education accounts, Bilibili learning zones) 32.1%, online knowledge repositories (e.g., Zhihu, Douban groups) 25.3%, social media (e.g., WeChat Official Accounts, QQ study groups) 21.6%, traditional education platforms (e.g., MOOCs, Learning Pass) 18.2%, and other channels 2.8%. While this multi-source approach broadens knowledge exposure, it also poses significant challenges. In interviews, 67.4% of teachers reported that students' assignments and classroom contributions frequently exhibit issues like "fragmented viewpoints" and "incoherent arguments." This reflects the core problem of fragmented knowledge acquisition leading to disjointed knowledge systems—a stark contradiction to the constructivist learning theory's central tenet that "knowledge must be structured to form meaning."

b. Learning Preferences: Visual-Driven Immersive Comprehension

Long-term exposure to visual content like images and videos in digital media has shaped digital natives' learning preferences toward visual dominance, directly impacting their engagement and knowledge internalization. Interview data reveals that 75.4% of students explicitly state, "Learning through visual formats like images and videos helps me focus better and retain information longer." Notably, this preference is significantly higher among secondary school students (81.2%) than university students (68.9%). Student interviews frequently included statements like "Pure text-based courseware makes me zone out, but content with animated demonstrations keeps my attention" and "Complex formulas become much easier to grasp when presented through visual charts," confirming the crucial role of visual stimuli in cognitive arousal.

Comparative data from case studies further substantiates the effectiveness of visual teaching. Among the three digital teaching pilot cases selected: Case A (high school physics mechanics course) employed traditional teaching methods with text-based courseware and chalkboard writing; Case B (same course) utilized a visual teaching approach featuring animation demonstrations, experimental videos, and visual force analysis diagrams; Case C (university computer programming course) adopted a hybrid format combining code demonstrations and visual flowcharts. Teaching effectiveness data revealed: Case B students demonstrated a 62.3% increase in classroom engagement (hand-raising frequency, group discussion participation duration) compared to Case A, with post-test average scores rising by 15.7%. In Case C, chapters utilizing process visualization charts achieved significantly higher assignment accuracy rates (89.2%) than those relying solely on code demonstrations (67.5%). These findings align closely with the theoretical assumption in the Technology Enhanced Learning (TEL) framework that "multimodal representations enhance learning outcomes," providing clear direction for digital pedagogy design.

c. Knowledge Construction: Collaborative Co-Creation

Unlike traditional learners' individual knowledge reception patterns, digital natives exhibit distinct collaborative characteristics in knowledge construction. Their ability to collaborate across time and space using digital tools reshapes knowledge generation pathways. Survey results indicate that 68.3% of students prefer group collaboration when completing learning tasks. Among them, 72.1% are proficient in using at least two online collaboration tools, with the most commonly used being Tencent Docs (65.4%), DingTalk group chats/meetings (58.7%), Feishu collaboration spaces (32.5%), and Notion shared databases (19.3%). Features like real-time editing, online annotation, and task assignment enable digital natives to transcend spatial and temporal constraints, achieving collaborative learning that seamlessly integrates synchronous and asynchronous modes.

The advantages of collaborative knowledge construction are particularly evident in group projects. In the questionnaire survey, 61.5% of students indicated that "discussing with peers through collaborative tools stimulates more innovative ideas," while 58.2% believed that "the exchange of perspectives during collaboration helps identify gaps in their knowledge." This characteristic aligns with the core constructivist learning theory that "knowledge is jointly constructed through social interaction," providing empirical support for designing collaborative teaching models in digital pedagogy. Notably, interviews revealed that 17.3% of students experienced issues such as "over-reliance on others during collaboration" and "inefficiency due to unclear division of labor," indicating that collaborative teaching requires scientifically guided organizational strategies.

Mismatch Between Traditional Education Models and Digital Natives

Traditional educational models emerged from the industrial era's demand for standardized talent cultivation. Their core logic—linear transmission, passive reception, and fixed scenarios—systematically conflicts with the cognitive patterns digital natives develop in digital environments: fragmented acquisition, active exploration, and ubiquitous learning. This mismatch is not a localized discrepancy but a comprehensive contradiction permeating instructional content, methods, and settings.

a. Instructional Content: Structural Conflict Between Linear Knowledge Systems and Fragmented Cognitive Habits

Under traditional education models, teaching content has always centered on "textbook chapters" as its primary vehicle, exhibiting distinct linear progression—teachers follow the logical sequence of knowledge, progressing from foundational concepts to complex applications, emphasizing the integrity of the knowledge system and the coherence of its logical chain. This design philosophy fundamentally conflicts with digital natives' information acquisition habits of "multiple-source divergence and fragmented integration." Survey findings reveal that 78.6% of digital native students find "chapter-by-chapter textbook instruction overly tedious," while 69.3% express a preference for "gathering knowledge from multiple sources around specific problems rather than learning in a fixed sequence."

A deeper contradiction lies in the gap between the "authoritative monopoly" of knowledge presentation and the digital natives' demand for "multiple verifications." In traditional teaching, textbooks and teacher explanations constitute the primary knowledge sources, carrying strong authority and exclusivity. Digital natives, however, habitually cross-verify knowledge through search engines, social media, online communities, and other channels, forming fragmented knowledge node networks. This disparity in needs leads to 42.7% of students experiencing "attention drift" in traditional classrooms, rooted in the linear knowledge system's inability to accommodate digital natives' fragmented cognitive pathways.

b. Teaching Methods: Conflict Between Unidirectional Instruction and Active Exploration

Traditional education has long adhered to a teacher-centered philosophy, establishing a one-way knowledge transmission model of lecture-note-taking-exercise. Students primarily function as passive knowledge recipients, lacking space for independent exploration and interactive collaboration. This approach is significantly mismatched with digital natives' learning preferences for active retrieval, collaborative creation, and instant feedback, manifesting in two major issues: lack of interaction and suppression of agency.

Regarding interactivity, traditional classrooms predominantly feature one-way exchanges where teachers pose questions and students respond, with limited frequency and depth of engagement. Survey data reveals that 63.2% of digital native students report "rarely having opportunities to ask questions proactively in traditional classrooms," while 71.5% feel "class discussion time is insufficient to fully

express their views." Teacher interviews further corroborate this issue: 82.4% of interviewed teachers admitted that "no more than 30% of students actively participate in traditional classrooms," and "most contributions come from a handful of high-achieving students, while the majority remain passively silent." Digital natives, accustomed to real-time interaction through comments, bullet chats, and online discussions in their daily information consumption, experience negative feelings of "insufficient learning engagement" due to this lack of interaction.

Regarding agency, traditional teaching emphasizes "teacher-led control over the pace and content of knowledge transmission," depriving students of the right to autonomously select learning materials or adjust their learning pace. This starkly contrasts with digital natives' proactive exploration tendencies—surveys reveal that 76.8% of students "prefer independently searching for learning resources to solve problems," while 67.4% "desire to prioritize learning content based on personal interests." Case tracking revealed that in a secondary school mathematics class using traditional lecture-based teaching, student distraction rates reached 47.3%. However, when teachers encouraged students to independently search for and discuss case studies around the theme of "function applications," distraction rates dropped to 18.6%. This contrast vividly illustrates how traditional teaching methods suppress student agency.

c. Teaching Scenarios: The Conflict Between Fixed Spaces and Times vs. Ubiquitous Learning Constraints

Traditional education centers on the "physical classroom + fixed class period" model, creating constraints of "synchronized time and centralized space." This setup fundamentally conflicts with digital natives' demand for "ubiquitous, fragmented" learning. In the mobile internet environment, digital natives have developed habits of "accessing information anytime, anywhere." Learning is no longer confined to specific times and spaces but integrates into fragmented moments within daily life.

These temporal and spatial constraints manifest in two dimensions: First, rigid temporal constraints. Traditional classrooms strictly adhere to scheduled periods, with fixed 45-minute class durations that fail to accommodate digital natives' "short-duration, high-frequency" learning rhythms. Surveys reveal that 89.1% of digital native students habitually "study for 10-20 minutes before taking a break," while the continuous lecture format of traditional classrooms causes 64.5% of students to report "attention waning after 20 minutes of class." Second, physical limitations in the spatial dimension mean that physical classrooms cannot meet the ubiquitous learning needs of digital natives. Case studies indicate that students have clear learning needs during fragmented scenarios such as commuting to and from school (38.2%), recess breaks (45.7%), and home leisure time (52.1%). They seek targeted learning resources like short knowledge-point videos or error analysis, yet traditional education confines access to classroom lectures or printed materials—failing to adapt to contextual learning needs.

Notably, this mismatch is not isolated but forms a vicious cycle: "Dull content leads to low engagement, low engagement intensifies scenario dependency, and scenario constraints further solidify content delivery patterns." In teacher interviews, 67.8% of educators stated, "The lower student engagement in a class, the more hesitant we are to alter teaching methods, resorting instead to more detailed lectures to ensure knowledge transfer." This reactive approach further exacerbates the cognitive disconnect between traditional models and digital natives.

Adaptation Dimensions and Strategies for Digital Pedagogy

Addressing the core characteristics of digital natives, fragmented cognition, visual preferences, collaborative construction, and ubiquitous learning, partial adjustments to traditional teaching methods are insufficient for systemic adaptation. A four-dimensional adaptation framework is required, guided by constructivist learning theory and grounded in technology-enabled learning (TEL) frameworks. This framework encompasses content restructuring, interactive enhancement, personalized pathways, and scenario integration. Through the digital reconstruction of teaching elements, it achieves precise alignment between instructional systems and the cognitive patterns of digital natives.

a. Instructional Content: Bidirectional Reconstruction through Fragmentation Deconstruction and Structured Integration

The core of adapting digital pedagogy to instructional content lies in resolving the tension between "fragmented acquisition" and "systematic construction." This is achieved through a bidirectional strategy of deconstruction followed by integration, ensuring alignment between knowledge transmission and cognitive habits. Specifically, this advancement occurs across three levels: content deconstruction,

resource provision, and system anchoring.

At the content deconstruction level, it breaks away from the linear chapter logic of traditional textbooks, decomposing complete knowledge systems into a three-tier structure: "micro-knowledge points → knowledge modules → knowledge clusters." Each micro-knowledge point focuses on a single core concept, with a duration controlled between 5-10 minutes, aligning with digital natives' short-attention-span information reception habits.

For resource provision, we build a multimodal micro-resource library, matching each micro-knowledge point with differentiated presentation formats. Beyond traditional text-based courseware, we prioritize developing three core resource types: short video explanations (e.g., animated demonstrations in the style of Douyin education channels), visual charts (e.g., mind maps and flowcharts), and audio interpretations.

Systemically, knowledge graph technology builds a visual knowledge association network to overcome the "knowledge silos" of fragmented learning. The knowledge graph clearly labels logical connections between micro-knowledge points and supports self-directed exploration along customized learning paths.

b. Interaction Design: Dual Empowerment Through Multimodal Stimulation and Collaborative Engagement

Addressing digital natives' visual learning preferences and collaborative construction needs, digital pedagogy's interaction design must achieve dual breakthroughs: diversifying sensory stimulation and fostering collaborative participation. By integrating multimodal resources with collaborative scenarios, it activates learner agency. The core of multimodal sensory stimulation lies in transcending the traditional text-and-image model by integrating immersive technologies to expand sensory dimensions. Visually, beyond conventional visualizations, AR technology enables overlaying virtual content onto real-world scenes. Audibly, contextualized audio designs are employed. Tactilely, VR devices facilitate hands-on simulation experiences. Collaborative participation design requires establishing digital collaboration platforms tailored to the habits of digital natives. Real-time online discussions facilitated by tools like DingTalk groups and Tencent Meeting should incorporate diverse interactive elements—such as quick-fire quizzes and polls—to stimulate student engagement and enable cross-temporal task collaboration. To enhance engagement and effectiveness, gamified collaborative learning models can be adopted. Design level-based learning games allowing students to complete learning and collaborative tasks in a relaxed and enjoyable atmosphere. Additionally, tools like Tencent Docs and Feishu collaboration spaces can be used to reasonably divide group tasks and track progress in real time, ensuring the entire collaborative process proceeds efficiently and orderly.

c. Learning Pathways: AI-Driven Personalization and Dynamic Adjustment

Digital natives exhibit significant individual differences in learning needs. Traditional one-size-fits-all teaching approaches struggle to meet their diverse requirements and achieve precise alignment. Therefore, it is essential to leverage advanced AI technology to build adaptive learning systems that enable personalized learning path customization.

During data collection, a multidimensional learning behavior database is constructed, primarily encompassing three core data categories: learning progress, learning effectiveness, and learning preferences. The pilot platform ingeniously employs tracking technology to automate data collection. Specifically, it meticulously records granular yet critical data points such as pause points and replay counts during instructional video viewing, as well as thinking duration during quizzes.

The intelligent analysis phase relies primarily on AI algorithm models. Through deep mining and analysis of collected learning data, these models generate precise "cognitive profiles" for each student. Based on these profiles, the system gains intelligent judgment and dynamic adjustment capabilities: Upon a student's successful completion of foundational tasks, the system automatically pushes matched advanced learning resources to further enhance their abilities. Conversely, when the system detects a student consistently missing questions, it automatically reduces the difficulty of learning tasks and precisely delivers corresponding supplementary learning materials to aid deeper understanding and mastery of knowledge.

d. Teaching Scenario: Building a Ubiquitous Learning Ecosystem with Virtual-Physical Integration

Given that digital natives demand ubiquitous learning anytime, anywhere, traditional digital pedagogy must transcend the temporal and spatial constraints of physical classrooms. This requires achieving a blended teaching environment that integrates "online virtual learning + offline physical

interaction," thereby realizing comprehensive coverage of learning scenarios across all times and spaces. To extend these scenarios, learning resources and services must be expanded beyond physical classrooms into ubiquitous settings. On one hand, mobile learning platforms should be established, enabling students to access micro-resource libraries and participate in online assessments anytime, anywhere via smartphones, tablets, and other mobile devices, thereby breaking the shackles of time and space. On the other hand, scenario-based learning tasks should be designed, where systems automatically recognize students' physical contexts and precisely deliver relevant knowledge, organically combining field observation with digital empowerment to provide richer and more diverse learning experiences. Regarding model integration, a blended learning approach is adopted: "Online Preview - Offline Interaction - Online Consolidation." During the online preview phase, the focus is on cultivating students' independent learning abilities, allowing them to explore and familiarize themselves with the content beforehand. The offline interaction phase centers on deepening understanding through interactive activities, where teachers provide on-site guidance, students perform practical operations, and engage in in-depth discussions about issues encountered during the online preview, promoting knowledge internalization and application. The online consolidation phase pushes learning resources such as experiment report templates and error analysis to students via mobile devices, helping them reinforce knowledge and enhance learning outcomes. For process monitoring, intelligent devices and sensors enable comprehensive data collection throughout the learning journey. Teachers can adjust instructional strategies in real-time based on this monitoring data.

It is crucial to emphasize that content adaptation, interaction design, path customization, and scenario construction are not isolated, independent dimensions. Rather, they form an organic whole centered on content, facilitated by interaction, supported by pathways, and secured by scenarios. Together, they drive the construction and refinement of a ubiquitous learning ecosystem that integrates virtual and physical dimensions.

5. Conclusion

This study examined the cognitive characteristics of digital natives and identified three key traits that shape their learning behaviors: fragmented information acquisition, a preference for visual learning, and collaborative knowledge construction. These characteristics challenge traditional educational models and highlight the need for pedagogical transformation. To address this issue, the study proposes a digital pedagogy framework consisting of fragmented content integration, multimodal interaction, AI-adaptive learning pathways, and blended virtual–physical learning environments. Empirical findings indicate that this framework can enhance students' learning engagement and support more effective knowledge internalization in digital learning contexts.

The study also contributes theoretically and practically to the development of digital education by linking digital natives' cognitive traits with the design of digital pedagogy. The proposed framework provides guidance for educators in implementing more adaptive teaching strategies and offers references for policymakers in advancing educational digitalization. Nevertheless, this study has several limitations, including limited sample diversity and short observation duration. Future research should expand the sample scope, conduct longitudinal investigations, and explore the integration of emerging technologies such as artificial intelligence, blockchain, and the metaverse in digital pedagogy.

REFERENCES

Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon, 9*(5), 1–6.

Brown, J. S. (2000). Growing up digital: How the web changes work, education, and the ways people learn. *The Magazine of Higher Learning, 32*(2), 10–20.

Ke, Z., & Huang, Y. (2009). Images better than text? N generations of students and cognitive development. *Journal of Education Research, 193*, 15–23.

Bennett, S., Maton, K., & Kervin, L. (2008). The 'digital natives' debate: A critical review of the evidence. *British Journal of Educational Technology, 39*(5), 775–786.

Zhao, Y. (2014). Digital insight: A preliminary exploration based on the concepts of digital natives and digital immigrants. *Chinese Journal of Library Science, 40*(6), 43–54.

Hui, L., Wang, J., & Li, D. (2024). Research dynamics and trends on digital natives domestically and internationally based on CiteSpace. *Journal of Hangzhou Dianzi University, 20*(4), 71–78.

Huang, R., Liu, D., Liu, X., et al. (2023). Digital pedagogy: Conceptual framework and implementation pathways. *Research on Modern Distance Education, 35*(1), 1–14.

Bonk, C. J., Graham, C. R., Cross, J., et al. (2009). The handbook of blended learning: Global perspectives, local designs. *Turkish Online Journal of Distance Education, 10*(4), 181–181.

Allen, I. E., & Seaman, J. (2003). Sizing the opportunity: The quality and extent of online education in the United States, 2002 and 2003. *Sloan Consortium Report*, 659–673.

Wang, Y., & Zheng, Y. (2023). Real-world challenges, implication reconstruction, and model construction of personalized learning in the intelligent era. *Research on Educational Technology, 44*(3), 28–35.

Hu, H., & Dong, Y. (2017). Technology facilitating deep learning: Theoretical construction and empirical research on "personalized-collaborative" learning. *Journal of Distance Education, 35*(3), 48–61.

He, K. (1997). Constructivist teaching models, methods, and instructional design. *Journal of Beijing Normal University (Social Sciences Edition)*, (5), 74–81.

Liu, S. (2000). A new model for human information acquisition and processing in the network era: The two-level three-cycle processing approach. *Chinese Journal of Educational Technology*, (4), 11–13.

Kennedy, G., Judd, T. S., Churchward, A., Gray, K., & Krause, K. (2008). First-year students' experiences with technology: Are they really digital natives? *Australasian Journal of Educational Technology, 24*(1), 108–122.

Kennedy, G., Judd, T., Dalgarno, B., et al. (2010). Beyond natives and immigrants: Exploring types of net generation students. *Journal of Computer Assisted Learning, 26*(5), 332–343.

Helsper, E. J., & Eynon, R. (2010). Digital natives: Where is the evidence? *British Educational Research Journal, 36*(3), 503–520.

Liu, S. N. Y., & Hao, X. H. (2024). Challenges and approaches for generative AI in educational innovation. *Tsinghua University Journal of Education, 45*(3), 1–12.