# An AI-Enabled Smart Elderly Education Service Ecosystem From An Integrated Medical, Elderly Care, And Education Perspective

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*Received March 16, 2026; accepted April 21, 2026*

Population aging is accelerating worldwide, placing increasing pressure on healthcare systems and elderly care services. Although elderly education is recognized as an important component of active and healthy aging, existing services remain fragmented, with limited coordination among medical, care, and educational sectors. Meanwhile, advances in artificial intelligence (AI) offer new opportunities to support personalized and preventive interventions, yet their effective integration into elderly education and care remains insufficiently explored. This study proposes an AI-enabled smart elderly education service ecosystem from an integrated medical, elderly care, and education perspective. Drawing on service ecosystem theory and collaborative governance theory, the study conceptualizes medical services, elderly care, and education as interdependent subsystems and positions elderly education as a central intervention mechanism. A qualitative-oriented approach combining literature analysis and system modeling is adopted to design a layered architecture and an AI-centered operational mechanism. The results present an integrated service ecosystem supported by an AI middle platform that enables data fusion, personalized learning recommendations, and cross-domain coordination. Through mechanism-based analysis and scenario simulation, the proposed model demonstrates clear advantages over traditional fragmented approaches in terms of service integration, personalization, and preventive support. This study provides a conceptual framework and practical insights for developing sustainable and human-centered elderly education services in aging societies.

**Keywords:** Smart Elderly Education; Integrated Care; Service Ecosystem; Artificial Intelligence; Collaborative Governance

http://dx.doi.org/10.6180/jase.202610_33.037

## 1. Introduction

Population aging has become a defining demographic trend worldwide, posing profound challenges to health systems, social services, and long-term care arrangements. As life expectancy continues to increase, a growing proportion of older adults are living longer with chronic conditions and functional limitations, placing sustained pressure on already constrained healthcare resources [1]. At the same time, population aging is no longer viewed solely as a societal burden but also as a structural transformation that reshapes labor markets, innovation systems, and social participation patterns [2]. These dynamics highlight the urgency of developing sustainable approaches that support health, independence, and quality of life in later life. In response, the concept of active and healthy aging has gained increasing attention. It emphasizes not only disease management but also the maintenance of physical function, cognitive capacity, mental well-being, social engagement, and sleep quality [3].

In China, the aging process is particularly rapid. As shown in Figure 1, based on data from the China Statistical

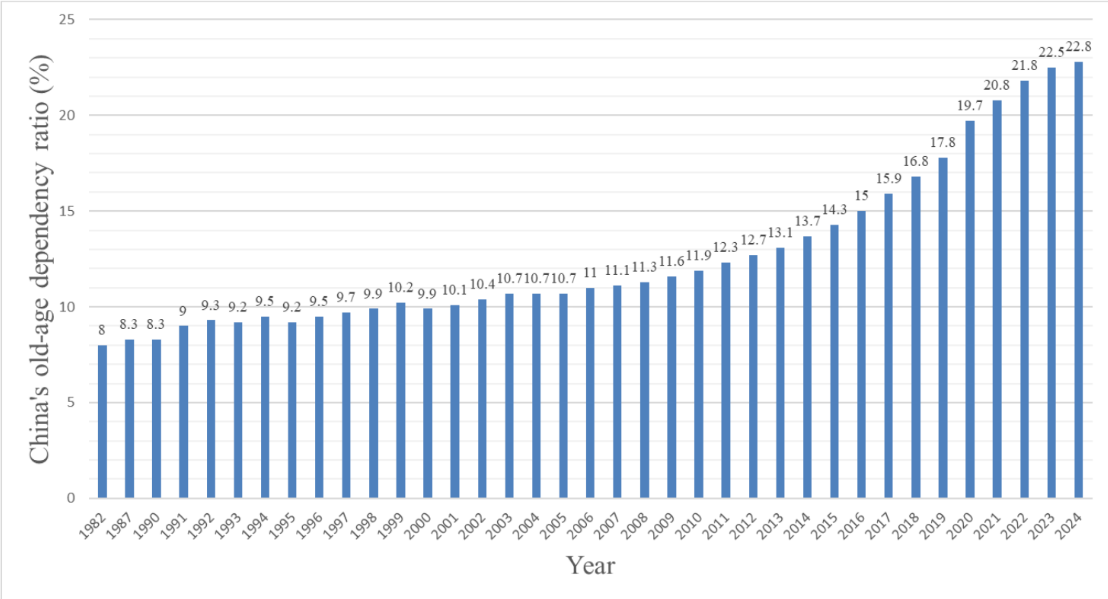


**Fig. 1.** Trends in China's old-age dependency ratio from 1982 to 2024 (data source: China Statistical Yearbook 2025).

Yearbook (2025), the old-age dependency ratio increased from 8.0% in 1982 to 22.8% in 2024. The growth has accelerated significantly since 2010, with a sharp rise after 2015. This trend indicates a rapidly intensifying burden on the working-age population and reflects a deepening imbalance between the demand for elderly services and the capacity of existing support systems.

Despite growing demand, current service structures remain fragmented, with healthcare, elderly care, and education operating largely in parallel rather than in coordination. This fragmentation limits the effectiveness of interventions aimed at promoting active and healthy aging. Therefore, from a data-driven perspective, the escalating dependency pressure underscores the urgent need to develop integrated service models that can enhance resource efficiency and service continuity. In this regard, constructing a smart elderly education service ecosystem under the integration of medical care, elderly care, and education becomes a critical pathway to addressing the challenges of population aging. However, achieving active aging requires more than medical interventions alone; it demands mechanisms that empower older adults to understand, manage, and adapt their behaviors in everyday contexts. Lifelong learning and elderly education play a critical role in this process. Research has consistently shown that continued learning in later life contributes to cognitive resilience, health literacy, and social participation, thereby supporting autonomy and self-regulation [4, 5]. Beyond formal education systems, elderly education increasingly encompasses health education, self-management skills, and adaptive learning tailored to individual needs. At the same time, differences in attitudes toward and acceptance of technology across generations indicate that educational approaches must be sensitive to older adults' preferences, capabilities, and motivations [6]. These findings underscore that elderly education is not merely a supplementary activity but an essential component of strategies aimed at fostering active aging and sustaining independence in aging populations.

Despite growing recognition of the complex and multidimensional needs of older adults, current health, care, and education services remain largely fragmented and siloed. Healthcare systems are typically organized around disease-specific and institution-centered models. However, these models are poorly aligned with the realities of multimorbidity, functional decline, and social vulnerability in later life [7, 8]. Older adults bear a disproportionate burden of chronic diseases. Yet they are often underrepresented in clinical trials and inadequately served by guideline-driven care, leading to gaps between clinical recommendations and real-world practice. These gaps are further exacerbated by social and economic factors, including isolation, financial constraints, and unequal access to specialized geriatric services. This highlights the limitations of narrowly medicalized approaches.

Elderly care services and community-based support systems frequently operate independently from formal healthcare and educational structures. Workforce shortages in geriatric medicine and long-term care have led to significant service gaps, particularly in community and home-based settings, where most older adults reside [9]. Although innovative care models and co-management approaches have emerged, their implementation is often localized and lacks systematic integration across sectors. Technology-enabled solutions have been proposed to address some of these challenges. However, their adoption and effectiveness are constrained by fragmented implementation and limited user acceptance. Studies on smart home technologies and wearable healthcare devices show that older adults and caregivers recognize their potential to support autonomy and aging in place [10]. However, these technologies cannot function as stand-alone solutions and must be integrated into broader care and support frameworks. Moreover, acceptance of digital health technologies among older adults is influenced by factors such as technology anxiety, resistance to change, and perceived relevance to daily life, indicating that purely technology-driven interventions are insufficient [11]. Existing approaches reveal a persistent lack of coordination among medical services, elderly care, and educational interventions. Fragmented service delivery, siloed data systems, and weak alignment between professional expertise and everyday self-management limit the effectiveness of current models. These limitations point to a critical research gap: the need for an integrated service framework that connects healthcare, care environments, and elderly education through coordinated mechanisms, enabling personalized, continuous, and context-aware support for older adults.

Recent advances in artificial intelligence have expanded the potential of digital technologies to support healthcare delivery and learning processes, particularly through AI-enabled services and decision-support systems. In healthcare, AI has been shown to enhance precision medicine by improving diagnostic accuracy, supporting personalized treatment strategies, and enabling cost-effective allocation of medical resources [12]. Evidence from economic evaluations suggests that AI-based interventions can deliver modest but meaningful health gains at relatively low incremental costs, highlighting their promise for large-scale adoption. Intelligent wearable sensors empowered by machine learning facilitate continuous, non-intrusive health monitoring and enable a shift from hospital-centered care toward more decentralized, patient-centric models [13]. These developments are especially relevant for older adults, whose health management increasingly depends on long-term monitoring and timely, personalized interventions. Beyond healthcare, AI has also demonstrated substantial potential in education by enabling personalized and adaptive learning experiences. Studies in AI-supported education show that intelligent systems can tailor content, pacing, and feedback to individual learners, thereby enhancing learning effectiveness and engagement [14]. In medical and health sciences education, generative AI and large language models have been explored as tools to support teaching, learning, and the development of digital competencies, suggesting new possibilities for scalable and flexible educational support [15]. These advances indicate that AI can act as a powerful mediator between complex professional knowledge and learners' individualized needs. However, growing evidence also points to important risks and limitations associated with AI integration. The value of AI-enabled systems is highly heterogeneous and sensitive to modeling choices, system design, and contextual factors, leading to uncertainty in real-world adoption and impact [12]. In educational contexts, concerns have been raised regarding overemphasis on technical performance at the expense of human-centered outcomes, ethical considerations, and learner well-being [16]. AI tools, such as chatbots, may produce mixed emotional and motivational effects, with user familiarity and support conditions strongly moderating their impact [17]. These risks are particularly salient for older adults, who may experience technology anxiety, lower digital literacy, and heightened sensitivity to opaque or overly automated systems.

Existing research suggests that the value of AI lies not in autonomous decision-making but in its role as an assistive and augmentative technology. A human-in-the-loop approach, in which AI provides recommendations, coordination, and analytic support while human professionals retain oversight and final authority, is increasingly recognized as essential for ensuring safety, trust, and ethical compliance. This perspective underscores the need to embed AI within carefully designed service ecosystems that align technological capabilities with human judgment, institutional responsibilities, and the everyday contexts of older adults. Against this backdrop, this study positions itself at the intersection of smart elderly education, integrated care, and AI-enabled service innovation. Drawing on a service ecosystem perspective, the research conceptualizes medical services, elderly care, and education as interconnected components within a unified system that co-creates value through coordinated actors, shared resources, and institutional arrangements. Rather than treating education as a peripheral or supplementary service, this study reframes elderly education as a central intervention mechanism that translates medical expertise and care needs into actionable learning experiences embedded in everyday life.

This study proposes an AI-enabled smart elderly education service ecosystem that integrates medical knowledge, care contexts, and educational delivery through an AI middle platform. By embedding AI as a decision-support and coordination layer, the proposed model enables data-driven personalization, cross-domain collaboration, and continuous feedback while preserving human oversight and professional accountability. In addition, the study incorporates a collaborative governance perspective to clarify role boundaries and coordination mechanisms among hospitals, care providers, educational institutions, and technology platforms, addressing the governance challenges commonly observed in fragmented service systems.

The main contributions of this study are summarized as follows:

- From a theoretical perspective, this study extends the service ecosystem and collaborative governance frameworks to elderly education. It treats medical services, elderly care, and education as interdependent components within an integrated system, rather than isolated sectors.
- From a system design perspective, this study proposes an AI-enabled smart elderly education service ecosystem. The system integrates medical knowledge, care contexts, and educational delivery through an AI middle platform. It also clarifies the roles and boundaries of key actors and shows how AI supports personalization and coordination in a human-centered way.
- From a mechanism and analytical perspective, this study develops a mechanism-based framework. It explains how integrated medical–care–education services improve service precision, continuity, and preventive intervention. These improvements are achieved through data fusion, closed-loop collaboration, and human-in-the-loop decision support. The framework also provides a foundation for future empirical validation and policy implementation.

## 2. Materials and methods

This study employs a hybrid approach to construct and evaluate an AI-enabled smart elderly education service ecosystem that integrates healthcare services, elderly care, and lifelong learning. The research materials, theoretical foundation, and methodological framework are illustrated in Fig. 2.

### 2.1. Research Materials

The research was conducted in a community-based elderly service context in Hangzhou China, involving older adults aged 60 and above, educators, healthcare professionals, and elderly care staff. Participants were recruited through purposive sampling to ensure representation across education, medical, and care domains.

Research materials included three main categories. First, educational data such as course curricula, learning records, and participation logs from elderly education programs. Second, care- and health-related data, including de-identified functional assessments and routine service records, collected under informed consent and strict data governance protocols. Third, qualitative materials, comprising semi-structured interviews and focus groups with key stakeholders to capture service needs, coordination challenges, and perceptions of AI-assisted support.

### 2.2. Theoretical Basis

This study is grounded in ecosystem theory and collaborative governance theory to explain the necessity and feasibility of integrating medical services, elderly care, and education into a unified service framework.

First, ecosystem theory provides a conceptual foundation for viewing medical care, elderly care, and education as an interconnected service ecosystem rather than isolated subsystems. In this perspective, older adults, service providers, and institutional actors coexist within a dynamic environment characterized by resource exchange, mutual dependence, and value co-creation. Educational activities enhance cognitive and social vitality, medical services ensure health security, and care services provide daily-life support; together, they form a synergistic structure that supports active and healthy aging [18]. Ecosystem theory thus explains why fragmented service provision often leads to inefficiencies, whereas integrated designs enable sustainable and adaptive elderly services.

Second, collaborative governance theory explains how multiple heterogeneous actors can jointly participate in the governance and operation of such an ecosystem. In integrated elderly services, hospitals, educational institutions, care organizations, technology providers, and public authorities possess distinct goals, resources, and professional logics. Collaborative governance emphasizes cross-sector coordination mechanisms, shared decision-making, trust building, and institutional arrangements that enable these actors to move beyond organizational boundaries [19]. This theoretical lens supports the design of coordination mechanisms and clarifies the role of AI as a facilitative tool rather than a replacement for human judgment.

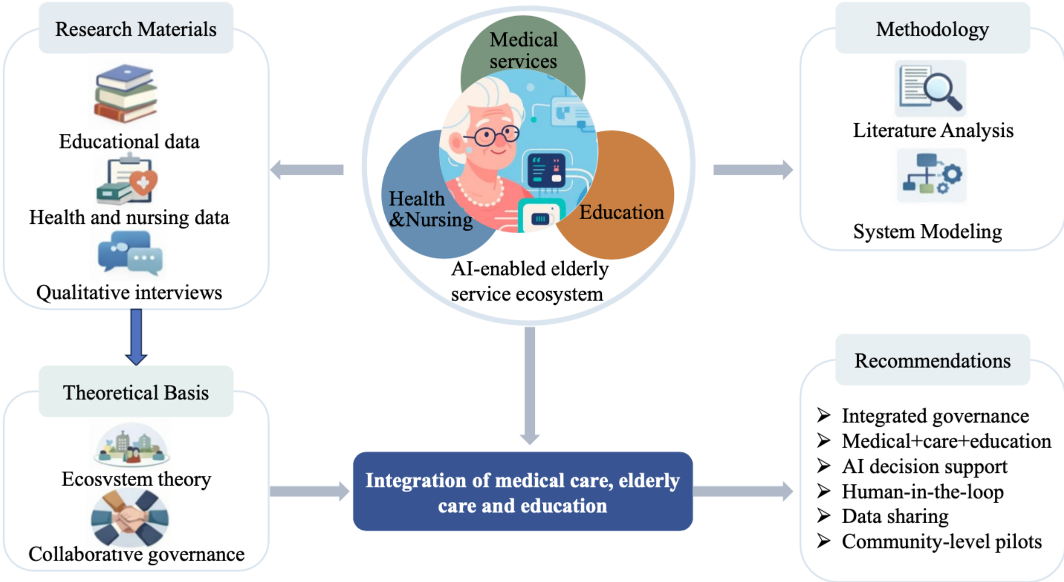


**Fig. 2.** Research framework of the AI-enabled smart elderly education service ecosystem.

### 2.3. Methodology

This study employs a qualitative-oriented design methodology combining literature analysis and system modeling.

First, a literature analysis method is used to systematically review existing research on elderly education, integrated care, and smart elderly service systems. By examining prior models, policy frameworks, and technological solutions, the study identifies common limitations, including fragmented service delivery, weak cross-sector coordination, and insufficient personalization for older adults. This analysis provides the problem basis and design requirements for the proposed ecosystem.

Second, a model construction method based on systems engineering principles is applied to design the integrated service ecosystem. Medical services, elderly care, and education are modeled as interacting subsystems connected through information flows, service processes, and governance mechanisms [20]. The overall architecture emphasizes modular design, functional coupling, and coordination efficiency, enabling adaptive service delivery and scalable system evolution. This modeling approach supports a structured translation of theoretical concepts into an operational ecosystem framework.

## 3. Results and discussion

Figure 3 illustrates the evolution of the proportion of the population aged 65 and above in China from 1982 to 2024. The data used in this study were obtained from the China Statistical Yearbook (2025) compiled by the National Bureau of Statistics, specifically from the dataset on population age structure and dependency ratios. Based on these longitudinal statistical data, a trend analysis was conducted to examine the dynamics of population aging. The results show a continuous and accelerating increase in the aging population, reflecting the deepening process of demographic aging in China. From 1982 to 2000, the proportion increased gradually from 4.9% to approximately 7.0%, indicating that China was still in the early stage of aging. After 2000, the growth rate began to accelerate, with a more pronounced upward trend observed after 2010. By 2024, the proportion reached 15.6%, more than tripling compared to 1982, which highlights a significant structural shift in the population.

Notably, the slope of the curve becomes steeper after 2015, suggesting a transition from gradual aging to rapid aging. This shift is closely related to declining fertility rates and increasing life expectancy. From a methodological perspective, the analysis reveals a clear stage-wise evolution characterized by "slow growth–accelerated growth–rapid deepening." The increasing proportion of elderly population also implies rising dependency pressures and growing demand for integrated public services. The findings indicate that China is transitioning toward a deeply aging society. This demographic trend provides strong empirical support for the necessity of constructing integrated service systems that combine healthcare, elderly care, and education.

In this study, the results are manifested in the con-

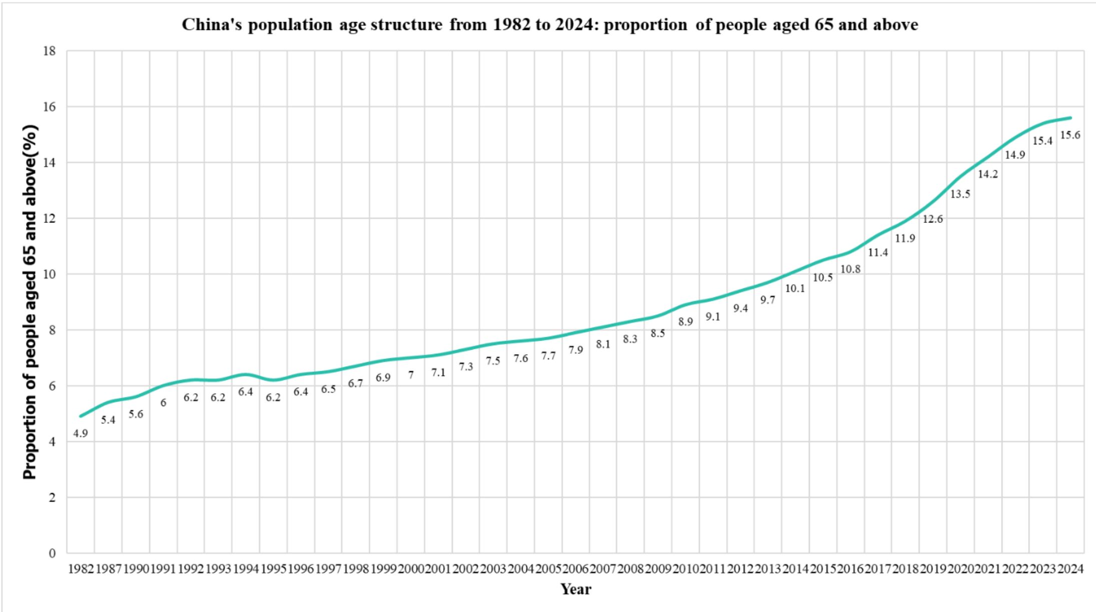


**Fig. 3.** Trends in the proportion of the population aged 65 and above in China from 1982 to 2024. The figure shows a continuous and accelerating increase in the aging population, indicating a transition from early-stage aging to a deeply aging society.

struction of an AI-enabled integrated medical–elderly care–education service model and its operational mechanisms, while the discussion focuses on why this model is expected to outperform conventional fragmented service modes in terms of coordination efficiency, intervention precision, and service continuity. Since this research is model- and mechanism-oriented, the evidence is provided through explicit architectural specifications, process logic, comparative reasoning, and scenario-based simulation, which together demonstrate feasibility and explanatory power.

### 3.1. System Architecture Design

The main achievement of this research is the construction of a smart elderly education service ecosystem centered on artificial intelligence, as shown in Fig. 2. This system integrates medical services, elderly care, and education functions. The entire system adopts a layered design, including a perception layer, a data layer, a service layer, and an application layer. This layered design integrates data collection, data processing, intelligent decision support, and service delivery, thereby ensuring the system's scalability, traceability, and privacy protection.

**Perception layer (multi-source sensing and low-burden collection):** The perception layer is responsible for acquiring multi-source signals from community and household care environments, as well as learning platforms. This layer collects non-invasive daily-life data, such as sleep patterns, physical activity, and dietary behaviors. It also incorporates service interaction traces, including course attendance, learning duration, completion of micro-tasks, and caregiver notes. A key design principle is "low burden and inclusiveness." The system remains functional even with partial data. This improves practicality in real-world settings, where sensors, devices, and digital literacy vary widely among older adults.

**Data layer (standardization, quality control, and privacy-by-design):** The data layer integrates heterogeneous data originating from medical institutions, elderly care settings, and educational platforms and serves as the foundation for cross-domain interoperability. Its primary role is to transform disparate data into a coherent and usable form while ensuring data quality and governance compliance. To achieve this, the data layer unifies terminologies, units, and data formats across domains. It performs preprocessing tasks, such as missing-value handling, outlier detection, and temporal alignment. It also enforces governance mechanisms, including role-based access control, consent management, and audit logging. Secure data exchange interfaces are implemented to support controlled information sharing between institutions, enabling integration without requiring full data centralization. Through these functions, the data layer balances interoperability, reliability, and privacy protection, thereby providing a trust-

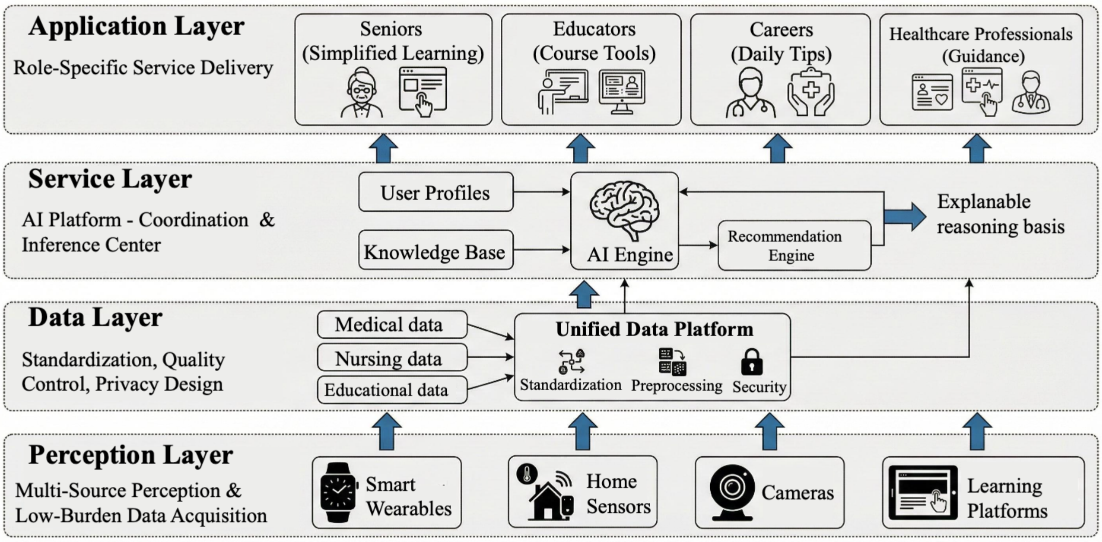


**Fig. 4.** An architecture diagram of a smart elderly education service ecosystem with artificial intelligence at its core.

worthy basis for downstream intelligent services.

**Service layer (AI middle platform as a coordination and reasoning hub):** The service layer constitutes the core intelligence of the system and is supported by an AI middle platform that operates as a coordination and reasoning hub. Rather than replacing human professionals, the platform aggregates and interprets multi-source information to support decision-making and service coordination. At this layer, raw and preprocessed data are first transformed into meaningful features and indicators that reflect health status, functional conditions, and learning behaviors. These indicators are then integrated into multi-dimensional user profiles capturing health-related needs, functional constraints, learning preferences, and available support resources. Building on these profiles, the AI platform aligns user needs with evidence-based medical knowledge and geragogical teaching strategies, enabling the generation of personalized learning recommendations and coordinated tasks across roles such as educators, caregivers, and care staff. To maintain transparency and trust, recommendation outputs are accompanied by interpretable rationales and risk-control mechanisms, including safety constraints and human review for high-impact decisions. In this way, the service layer enables personalized, explainable, and accountable intelligence that supports integrated elderly education and care services.

**Application layer (role-specific service delivery):** At the application layer, integrated services are delivered through role-specific interfaces. Elderly education institutions and online platforms serve as the primary service outlets. They deliver personalized learning content and health-related interventions in accessible forms, such as simplified interfaces, voice guidance, and stepwise tasks. For educators, the system provides tools for curriculum adaptation and engagement monitoring. For caregivers and community care staff, it provides actionable prompts embedded in daily routines, such as reminders aligned with learning goals. For medical professionals, the system provides a lightweight interface for remote guidance and knowledge-base updates, ensuring medical expertise is injected into the ecosystem without requiring clinicians to become course instructors.

Within this architecture, the roles of the key elements are explicitly bounded to avoid responsibility ambiguity. Medical institutions contribute evidence-based guidance via structured knowledge bases and remote professional input, rather than direct instructional delivery. Elderly care services provide contextual and behavioral data and act as the real-life execution environment where learning is translated into behavior. Educational institutions translate medical and health-related recommendations into pedagogically appropriate content, ensuring feasibility and sustained engagement. The AI middle platform connects these elements by enabling data-driven personalization, task orchestration, and traceable decision support.

### 3.2. Operational Mechanism Analysis

Based on the proposed architecture, an integrated operational mechanism is established to ensure effective collaboration among medical, care, and educational services.

A core mechanism is data fusion, which enables the transformation of medical and care data into educational interventions. For example, routine health assessment data can be interpreted by the AI platform to identify potential health risks or management needs. These insights are then mapped to corresponding educational content, generating personalized learning plans that align with the individual's health condition and daily-life context.

Building on data fusion, a closed-loop service collaboration process is formed. First, potential health or functional issues are identified through continuous data monitoring and analysis. Second, the AI platform generates personalized educational recommendations, such as health literacy courses or behavior-guidance learning modules. Third, older adults engage in learning activities delivered by elderly education platforms, supported when necessary by caregivers or community staff. Finally, post-learning behavioral and outcome data are fed back into the system, allowing dynamic adjustment of recommendations and continuous optimization of service delivery.

This mechanism enables a shift from reactive service provision to proactive and preventive intervention. Education becomes an integral component of health and care management rather than an isolated activity, while AI facilitates coordination without undermining professional autonomy.

### 3.3. Benefit Analysis and Comparative Discussion

To evaluate the effectiveness of the proposed model, this study adopts a comparative analysis and scenario simulation approach. First, a table-based comparison is used to contrast the traditional fragmented service model with the proposed integrated medical–elderly care–education ecosystem. In the traditional model, medical services, care services, and education operate independently, leading to duplicated resource use, limited personalization, and weak continuity of intervention. In contrast, the integrated model demonstrates higher resource utilization efficiency, improved service precision through data-driven personalization, and stronger continuity across service stages.

Second, a scenario simulation is conducted to illustrate the practical operation of the system. Taking the example of an older adult with hypertension, the system identifies risk-related indicators through routine health data. The AI platform then recommends a tailored set of educational courses focusing on blood pressure management, physical activity, and dietary habits. The older adult participates in these learning activities via an elderly education platform, while daily behavioral data are continuously monitored. Over time, feedback data indicate improved self-management behaviors, enabling the system to refine recommendations and support sustained health improvement.

Through comparative analysis and scenario-based reasoning, the proposed ecosystem demonstrates its potential to enhance service integration, support preventive health management, and improve the overall effectiveness of elderly education. These results indicate that the AI-enabled integrated model provides a feasible and advantageous alternative to conventional fragmented elderly service approaches.

## 4. Conclusions

This section concludes the study from three aspects. First, it summarizes the main research findings and theoretical contributions of the proposed AI-enabled integrated elderly education service ecosystem. Second, it discusses the practical and policy implications of integrating medical services, elderly care, and education under a collaborative governance framework. Finally, it identifies the limitations of the current study and outlines directions for future research.

### 4.1. Research Conclusions

This study proposes an AI-enabled smart elderly education service ecosystem from an integrated medical, elderly care, and education perspective. By drawing on ecosystem theory and collaborative governance theory, the research reframes medical services, elderly care, and education as mutually reinforcing subsystems that co-create value for older adults, rather than independent service domains. On this basis, the study constructs a layered architecture and specifies role boundaries: medical institutions contribute evidence-based knowledge and remote professional guidance; community and family care settings provide daily-life contextual and behavioral data; elderly education organizations act as the main delivery channel that transforms health and care needs into age-friendly learning experiences; and an AI middle platform connects these components through data processing, user profiling, recommendation, and coordination.

Beyond proposing an architectural blueprint, the study clarifies an operational logic that links "health/care needs" to "educational interventions" through a closed-loop mechanism. Specifically, multi-source data enable early identification of needs and risks; the AI platform translates these signals into individualized learning plans and supportive tasks; education interventions help improve health literacy, self-management skills, and engagement; and post-intervention feedback allows iterative adjustment and continuous service improvement. Conceptually, this demonstrates that elderly education can be positioned as a preventive and supportive intervention within an integrated care paradigm, rather than a peripheral welfare activity.

The study further contributes by articulating how AI can be used responsibly in integrated elderly services: AI is designed as a coordination and decision-support hub that enhances personalization and cross-sector collaboration while preserving professional autonomy and human accountability. Compared with traditional fragmented models, the proposed ecosystem is expected to reduce information discontinuities, lower coordination costs, and improve the precision and continuity of support. The research provides a systematic conceptual model, a mechanism-oriented explanation, and an implementation-ready logic that together offer a feasible pathway toward more effective, sustainable, and scalable elderly education services aligned with healthy and active aging goals.

### 4.2. Policy Implications

The findings provide several policy implications for building integrated and intelligent elderly service systems.

First, governance structures should shift from sector-based management toward integrated coordination. Policymakers may establish cross-department coordination mechanisms (e.g., joint steering committees, shared evaluation indicators, and unified service standards) to reduce fragmentation between healthcare, elderly care, and education. In particular, interoperability rules and data standards should be promoted to enable secure, role-based exchange of necessary information across institutions.

Second, elderly education should be recognized as an intervention tool that supports preventive health management and long-term care goals. Policy instruments can include targeted funding, service purchasing, and performance-based incentives for programs that translate medical and care needs into structured educational modules (e.g., chronic disease self-management, medication literacy, fall prevention, nutrition, and digital health literacy). Such institutional recognition can strengthen the continuity between diagnosis, daily care, and behavioral change.

Third, AI deployment should be accompanied by explicit governance requirements. Practical guidelines should emphasize privacy-by-design, data minimization, informed consent, and auditability. Meanwhile, accountability mechanisms should clarify which actors approve, supervise, and are responsible for AI-assisted recommendations, ensuring that AI supports rather than replaces professional decision-making.

Fourth, capacity building is essential for implementation. Policies should support digital inclusion for older adults and caregivers (training, accessible interfaces, community support), as well as cross-disciplinary workforce development for educators and care workers to collaborate effectively with medical professionals and AI-enabled workflows.

Based on these implications, it is recommended that governments and service providers conduct community-level pilot programs that integrate medical guidance, care data, and educational services through an AI middle platform. Pilot programs should adopt phased scaling: starting with high-demand scenarios (e.g., hypertension, diabetes, fall prevention), establishing standardized workflows and evaluation metrics, and then expanding to broader health and well-being education services once feasibility and effectiveness are confirmed.

### 4.3. Limitations and Future Research

This study has limitations that should be acknowledged. First, it is primarily conceptual and model-driven; the validation relies on comparative reasoning and scenario simulation rather than randomized or large-scale empirical evidence. Second, the model abstracts complex real-world conditions and may not fully capture heterogeneity in institutional readiness, regional infrastructure, and older adults' digital literacy, which can influence implementation outcomes. Third, while the study highlights governance considerations, detailed operational rules for data sharing, consent management, and accountability allocation require further elaboration in practice-oriented research. Fourth, the proposed AI-enabled mechanisms may face challenges such as data quality variability, model bias, explainability demands, and trust-related barriers among older adults and professionals.

Future research can proceed in four directions:

(I) **Empirical validation:** Implement pilot deployments and conduct longitudinal evaluations to measure educational outcomes (engagement, learning achievement, health literacy) and health/care-related indicators (self-management behaviors, service utilization, functional outcomes) while assessing cost-effectiveness and scalability.

(II) **Mechanism testing:** Examine which components of the ecosystem (e.g., recommendation, coordination workflows, caregiver involvement) contribute most to outcomes, and under what conditions they work best.

(III) **AI governance and ethics:** Investigate explainable and transparent recommendation strategies, fairness across different elderly groups, privacy-preserving data fusion, and human-in-the-loop approval mechanisms that maintain accountability.

(IV) **Cross-context comparison:** Evaluate how cultural factors, policy environments, and service delivery systems affect adoption and performance, thereby strengthening the generalizability and adaptability of the proposed ecosystem.

These research efforts would not only refine the conceptual framework but also provide robust evidence to support the wider adoption of AI-enabled integrated elderly education services in real-world settings.

## Acknowledgments

This study was supported by the 2021 Annual Planning Project of Zhejiang Education Science Planning, entitled "Research on Hangzhou's CUE Model of Elderly Education Based on the Theoretical Perspective of Embodied Cognition" (Grant No. 2021SCG018), and by the 2025 Key Project of Zhejiang Provincial Education Science Planning, entitled "Research on the Construction of an 'Intergenerational Learning' Community Support Service Paradigm Based on Learning Support Service Theory" (Grant No. 2025SB069). The principal investigator of both projects is Weina Guo. It was also supported by the project "Research on Innovation and Entrepreneurship Talent Cultivation Pathways for Engineering Majors in Agriculture-Related Universities under the Background of Artificial Intelligence" (Grant No. 231100751160537) and Zhejiang A&F University Higher Education Research Fund Project (Grant No. GJYB202614), with Le Yu as the principal investigator.

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