

Research progress on the application and development of medical–technology–education collaboration in science-based education for the aging population

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ABSTRACT

With the accelerating global trend of population aging, health management and science-based education for aging populations have become core public health priorities, and the synergistic integration of medical technology and education provides an innovative pathway to address this challenge. This review finds that theories including Social Cognitive Theory and Self-efficacy Theory offer a robust theoretical foundation for health education among aging populations, and that the application of digital tools—such as smartphone applications and wearable devices—significantly enhances educational effectiveness. However, current practices still face challenges including the digital divide and ethical concerns. Future efforts should promote personalized and intelligent development in science-based education for aging populations through interdisciplinary collaboration, technological optimization, and policy support, ultimately achieving healthy aging objectives.

KEYWORDS

aging population, medical technology, science-based education

1 Introduction

Developing a theoretical framework for health education in the aging population requires integrating multidimensional perspectives from psychology, sociology, and pedagogy. Social Cognitive Theory (SCT) emphasizes that individual behaviors are influenced by the interplay of self-efficacy, social support, and environmental factors. A qualitative study on physical activity (PA) among older adults after retirement revealed that self-efficacy beliefs, social support, and positive outcome expectations are key factors influencing PA participation [1]. Through seven focus groups, this study found that the lack of daily structure post-retirement may impede PA integration into routines, while PA adherence fosters a sense of purpose for older adults. This result validates the applicability of SCT in explaining health behaviors in the aging population, demonstrating that the synergy between self-efficacy and social support can effectively promote the maintenance of health behaviors.

Self-efficacy Theory also plays a core role in chronic disease management. A randomized controlled trial targeting older adults with diabetes showed that health education programs based on self-efficacy theory significantly enhanced foot self-

care behaviors while improving self-efficacy expectations and outcome expectations [2]. This study enrolled 76 older adults with diabetes; the intervention group demonstrated significantly better foot care knowledge and behavioral compliance than the control group after a 12-week self-efficacy enhancement program. Furthermore, the integrated application of the Information-Motivation-Behavior model (IMB) and Self-determination Theory (SDT) revealed the direct impact of autonomous motivation on diabetes self-management behaviors [3]. The cross-validation of these theories provides multidimensional theoretical support for health education in aging populations, emphasizing the synergistic effects of individual cognition, motivation, and social environment.

The advancement of medical technology has diversified the toolkit for health education among aging populations. Mobile health (mHealth) technologies transcend the temporal and spatial constraints of traditional education through SMS, applications, and other digital formats. A randomized controlled trial involving hypertension patients demonstrated that the health education group receiving SMS-based interventions significantly outperformed the control group

receiving only routine education in salt intake control and blood pressure monitoring behaviors [4]. This study recruited 420 patients with hypertension in rural Bangladesh. The intervention group received regular SMS reminders and health knowledge updates, resulting in significant reductions in both systolic and diastolic blood pressure after five months. Additionally, smartphone applications have demonstrated potential for use in cognitive screening. A high-frequency cognitive assessment study in older adults demonstrated that smartphone application-based self-management models show good reliability and validity, with participant compliance reaching 89.3% [5].

Remote monitoring technology applications further extend the educational value of medical technologies. Home-based remote monitoring systems enable older adults to track their health status through real-time data collection and feedback. A prospective cohort study revealed that this system significantly reduced readmission rates and emergency department visits among high-risk patients [6]. Furthermore, the application of virtual reality (VR) technology in fall prevention education has yielded preliminary results. For example, VR simulations of fall risk scenarios in home environments have significantly enhanced older adults' risk identification capabilities and preventive behaviors [7]. These technologies not only improve educational accessibility but also enhance older adults' self-management ability through personalized feedback.

Innovative applications of pedagogical theories provide methodological guidance for science-based education targeting the aging population. Transformative learning theory emphasizes behavioral change through critical reflection. The IGNITE project (Innovative Gerontological Nursing Intervention Mapping Initiative) developed a digital geriatric nursing curriculum based on this theory. This project significantly improved nurses' attitudes toward older adults and their dementia care knowledge through experiential learning and rational dialogue [8]. Furthermore, applying intergenerational learning theory effectively promoted knowledge transfer and intergenerational understanding. An antimicrobial resistance (AMR) knowledge intervention study for older adults in Hong Kong, China showed that intergenerational interactions with university students increased older adults' AMR knowledge scores from 40.1% to 83.3% [9].

Participatory learning theory enhanced educational outcomes through community collaboration. For instance, the Community Health Assessment Program for Emergency Medical Services (CHAP-EMS) significantly reduced blood pressure levels in older adults through one-on-one interactions between community nurses and older adults [10]. Implemented in low-income senior apartments in Hamilton, Canada, this project demonstrated effective control of both systolic and diastolic blood pressure among all 79 participants. Concurrently, diabetes risk assessment indicated a 15% reduction in risk level for participants. The application of these educational theories demonstrates that learner-centered interactive models better address the needs of the aging population, thereby enhancing the effectiveness of science-based education.

2 Methods

2.1 Research strategy

To systematically identify research on the application and development of medical-technology-education collaboration in science-based education for the aging population, we searched databases including PubMed, Web of Science, Google Scholar, the Cochrane Library, and EMBASE, with a cutoff date of April 1, 2026. The subject search terms used were as follows: #1 — “Aging population” or “Aging demographic” or “Older adults”; #2 — “Science-based education” or “Health education” or “Health literacy”; #3 — “Medical technology” or “Digital health” or “Wearable devices” or “Smartphone applications”; #4 — “Educational collaboration” or “Interdisciplinary collaboration” or “Medical-education collaboration”; #5 — #1 AND #2 AND #3; #6 — #1 AND #2 AND #4; #7 — #1 AND #3 AND #4.

2.2 Inclusion criteria

This review included all literature exploring the application and development of medical-technology-education collaboration in science-based education for the aging population. Inclusion criteria were as follows: Only original research, reviews, case reports, case series, opinion articles, and meta-analyses published in English and explicitly focusing on the aging population were included. Studies must involve applications of synergistic strategies between medical technology (e.g., digital tools, telemedicine, wearable devices) and education to enhance health literacy or science-based education effectiveness for the aging population. Literature discussing relevant theoretical foundations (e.g., Social Cognitive Theory, Self-efficacy Theory) and implementation challenges (e.g., digital divide, ethical issues) was also included.

2.3 Study selection

After manually removing duplicate literature, the titles and abstracts of articles retrieved from the initial search underwent preliminary screening. Subsequently, full texts of potentially relevant literature were thoroughly reviewed according to inclusion and exclusion criteria (Fig. 1). Following abstract screening, full-text eligibility assessments determined final inclusion or exclusion. Reviewer discrepancies were resolved through consensus meetings.

3 Historical evolution and current status analysis of science-based education for the aging population

3.1 Historical development of health education for the aging population

Health education for the aging population has evolved from single-disease management to comprehensive health promotion. Early education focused on acute disease treatment, while modern health management emphasizes prevention and self-care. A study of older adults in Japanese communities showed that regular group exercise significantly improved participants' functional health, social connectedness, and community engagement [11]. Through

four focus groups, this study found that exercise not only enhanced physical function but also strengthened social support and fostered a greater sense of community belonging among older adults.

The integration of digital technology has driven the transformation of health education since the beginning of the 21st century. For example, since 2010, mobile applications and wearable devices have been utilized for health monitoring and education among older adults. A study involving rural older adults in China indicated that health education incorporating digital tools significantly enhanced diabetes prevention knowledge [12]. This study, which included 434 rural older adults, revealed a positive correlation between education level and health knowledge scores. Moreover, global health policy initiatives, such as the WHO's "Healthy Aging" strategy, have further accelerated the dissemination of health education, emphasizing multi-sector collaboration and community participation.

3.2 Current applications of medical technology in education for the aging population

Currently, diversified applications of medical technology are emerging in education for the aging population, though challenges such as the digital divide persist. Smartphone applications are among the most prevalent tools; for instance, the "Care4Senior" app helps older adults manage chronic conditions through health knowledge dissemination and monitoring functions [13]. A pilot trial of this application in Singaporean communities demonstrated significant improvements in participants' health literacy and self-management abilities. Wearable devices are also increasingly utilized; smart bracelets, for example, promote physical

activity among older adults through step monitoring and sedentary behavior alerts [14]. An online walking program for retired older adults demonstrated enhanced e-health literacy among participants, though device usability still requires optimization.

Telemedicine technology application resolves challenges regarding medical resource accessibility. For example, China's Internet Plus Healthcare model delivers convenient health services to rural older adults through video consultations and online education. This study involving 876 urban older adults revealed that 62% of participants were willing to share health information via mobile phones, yet age and digital skills persisted as primary barriers [15]. Furthermore, artificial intelligence (AI) applications in cognitive assessment have progressed; the CatBoost model achieved an AUC of 0.737 for predicting 3-month mortality in elderly ischemic stroke patients by analyzing eight clinical indicators [16]. The application of these technologies offers new pathways for educating the aging population, but further optimization is needed to accommodate the needs of older adults.

3.3 Analysis of current educational models for the aging population

Current educational models for the aging population exhibit diversity, yet regional and group disparities persist. Community-based education serves as one primary approach. For instance, Japan's "Stay in Balance" project, featuring student-led multifactorial fall prevention courses, significantly enhanced older adults' balance and muscle strength [17]. This project enrolled 69 older adults, with the intervention group's Berg Balance Scale score improving from 44 to 49. Additionally, the family-organization collaborative model

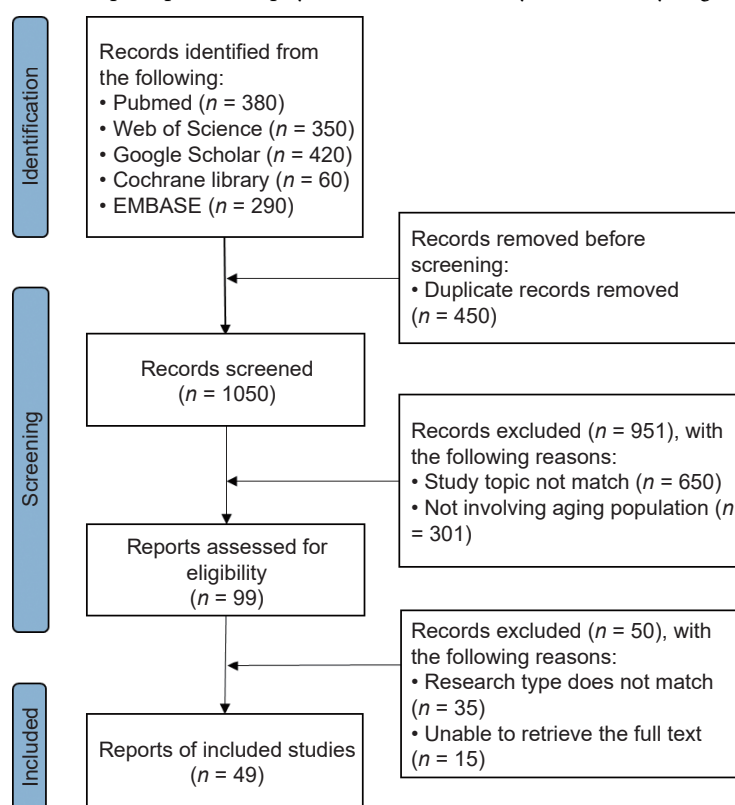


Figure 1 Research selection process of on the application and development of medical technology-education collaboration in science-based education for the aging population.

demonstrated significant effectiveness in chronic disease management. A study targeting older adults with diabetes revealed that family-involved health education significantly improved patients' medication adherence and quality of life [18].

However, the effectiveness of educational programs remains constrained by resource limitations and accessibility issues. For example, older adults in rural areas frequently encounter inadequate educational resources. Research in Nanjing, China demonstrated that rural older adults exhibit significantly higher prevalence of cardiovascular risk factors (including hypertension and obesity) compared to urban residents [19], while health education coverage remains substantially lower. Furthermore, the popularization of digital education still faces challenges. A survey in Heilongjiang Province, China revealed that only 38.6% of older adults use the Internet to access health information [20]. These current conditions indicate that future education models need to place greater emphasis on resource equality and technological adaptability to meet the needs of different groups.

4 Technological advancements in the application of medical technology for science-based education among the aging population

4.1 Digital tools for health education in the aging population

The development of digital tools provides efficient means for health education in the aging population. Smartphone applications serve as one of the core platforms. For instance, the "DanceMove" app promotes physical activity among older adults through step monitoring and interactive games [21]. The pilot application among community-dwelling older adults demonstrated improvements in participants' gait speed and balance, but long-term adherence requires further enhancement. The application of wearable devices has matured, with technologies like smart bracelets enabling older adults to monitor indicators such as blood pressure and blood sugar through real-time data feedback [22]. A study involving hypertension patients revealed that health education integrated with wearable devices significantly decreased systolic blood pressure [4].

Additionally, virtual reality (VR) and augmented reality (AR) technologies demonstrate potential in cognitive training applications. For example, VR simulates daily life scenarios to help older adults with cognitive impairment improve memory and decision-making abilities [7]. A study of older adults with mild cognitive impairment (MCI) demonstrated that VR training significantly improved patients' executive function and quality of life [23]. The diversity and personalized features of digital tools offer flexible and efficient solutions for health education in the aging population; however, further optimization of user experience is needed to increase adoption among older adults.

4.2 Innovative applications of medical technology in education for the aging population

Continuous innovations in medical technology are expanding the scope of science-based education for the aging population. AI-driven personalized education systems analyze user data to

deliver customized health recommendations. For instance, the AI-powered "Agatha" system integrates health monitoring with educational capabilities, providing older adults with real-time health guidance [24]. Through user profiling and behavioral analysis, this system enables targeted delivery of educational content. Furthermore, progress has been achieved in utilizing social robots for companionship and education, such as Japan's "Paro" robot, which improves older adults' mental health and cognitive abilities through interactive engagement [25].

The application of remote collaboration platforms facilitates the sharing of educational resources across regions. For example, China's "Internet+Nursing Service" model delivers professional health knowledge to rural older adults through video instruction and remote guidance [15]. Pilot implementation in Guangzhou demonstrated significantly improved adherence to healthy behaviors among participants. These innovative applications enhance educational accessibility while improving personalization and effectiveness through intelligent means, offering new directions for future science-based education for the aging population.

4.3 Effectiveness evaluation of technology-assisted teaching in education for the aging population

A study on the application of e-learning in drug prescription education for older adults showed that although the intervention group did not experience a significant reduction in potentially inappropriate medication (PIM) use, participants demonstrated significantly improved medication knowledge [26]. This study involving 697 hospitalized older adults found that e-learning courses enhanced physicians' understanding of geriatric pharmacology. Additionally, an effectiveness evaluation of VR in fall prevention education revealed a 30% reduction in fall incidence rates in the intervention group [7].

Effectiveness evaluations of wearable devices demonstrated that long-term use significantly improves physical activity levels among older adults. A study on patients with chronic heart failure demonstrated that exercise interventions incorporating wearable devices significantly increased daily step counts [27]. Furthermore, pilot evidence suggests that digital health interventions may support self-management after stroke; for example, the "iVERVE" feasibility trial found that electronically delivered support messages showed promise in assisting stroke survivors with goal attainment in areas such as function and participation, although between-group differences were not statistically significant. [28]. These evaluations indicate that technology-assisted education is significantly effective in science-based education for the aging population, but requires long-term follow-up and personalized adjustments to maximize benefits.

5 Epidemiology and pathological mechanisms of science-based education for the aging population

5.1 Epidemiological analysis of common health issues in the aging population

The epidemiological characteristics of common health

problems in the aging population exhibit diverse and complex features. Hypertension is one of the most prevalent chronic diseases, with a prevalence rate exceeding 50% among older adults globally [29]. A study on older adults in China revealed that the comorbidity rate of hypertension and depressive symptoms significantly increases healthcare resource utilization [30]. Additionally, epidemiological data on cognitive impairment indicate that approximately 50 million people worldwide suffer from dementia, with Alzheimer's disease accounting for 60%–70% of cases [31, 32].

Falls represent a significant health concern for the aging population, with approximately 30% of older adults experiencing falls annually worldwide [33]. A study on Chinese older adults revealed that fall incidence correlates significantly with age, gender, and health literacy. Furthermore, the comorbidity rate of Chronic Obstructive Pulmonary Disease (COPD) and sarcopenia among older adults reaches 20%, substantially increasing mortality [34]. These epidemiological data provide scientific basis for establishing objectives in science-based education for the aging population, highlighting the importance of integrated prevention and management of multiple comorbidities.

5.2 Pathological mechanisms of health issues in the aging population

The pathological mechanisms of health issues in the aging population involve interactions among multiple systems. Taking osteoporosis as an example, its pathological mechanisms include imbalances in bone metabolism, inflammatory responses, and hormonal changes. A study of postmenopausal women revealed that changes in serum protein biomarkers (such as fractalkine and TIMP-1) can predict the onset of osteoporosis at an early stage [35]. Furthermore, the pathological mechanisms of cognitive impairment are closely associated with β -amyloid protein deposition and hyperphosphorylation of tau proteins [31]. A study of older adults with MCI demonstrated a significant association between abnormal cerebral blood flow perfusion and cognitive decline [23].

Pathological mechanisms of chronic diseases additionally involve disruptions in gut microbiota balance. For example, diminished gut microbiota diversity in older adults with diabetes contributes to heightened inflammatory responses and insulin resistance [36]. Research conducted among older adults in China revealed a significant correlation between gut microbiota dysbiosis and the occurrence of metabolic syndrome [37]. Furthermore, sarcopenia's pathological mechanisms include decreased muscle protein synthesis and elevated oxidative stress, while exercise interventions enhance muscle function through mTOR pathway activation [38]. Research on these pathological mechanisms provides a scientific foundation for science-based education, helping older adults understand the intrinsic mechanisms of disease development and enabling them to implement targeted preventive measures.

5.3 The role of science-based education in health management for the aging population

Science-based education plays a critical role in health management for the aging population by significantly

enhancing adherence to healthy behaviors and disease prevention awareness. A study of older adults with diabetes demonstrated that health education combining family- and organization-based approaches significantly improved patients' foot self-care behaviors [2]. This study enrolled 76 patients; the intervention group's foot care knowledge score increased from a baseline of 65% to 85%. Additionally, science-based education for patients with hypertension significantly reduced their systolic blood pressure [4].

Science-Based Education also improves cognitive function and mental health in older adults. A study of older adults with MCI demonstrated that mindfulness training significantly enhanced patients attention and memory abilities [39]. Furthermore, intergenerational education programs involving university students' and older adults significantly reduced ageism [40]. These results demonstrate that science-based education not only enhances health knowledge among older adults but also comprehensively improves their health status and quality of life through behavioral modifications and psychological support.

6 Diagnostic technologies and treatment strategies for science-based education in the aging population

6.1 Early diagnostic technologies for health issues in the aging population

The advancement of early diagnostic technologies has provided crucial support for the prevention and intervention of health issues in the aging population. Biomarker detection serves as a principal method; for example, serum protein biomarkers such as fractalkine can enable early prediction of osteoporosis onset [35]. This study found that serum fractalkine levels in postmenopausal women were significantly correlated with bone mineral density through protein microarray technology. Additionally, advancements have been made in the application of imaging technology for diagnosing cognitive impairment; for instance, magnetic resonance imaging (MRI) can detect β -amyloid protein deposition in the brain [23]. A study on older adults with MCI showed that MRI-detected hippocampal volume reduction was significantly associated with cognitive function decline [41].

The application of wearable devices enables real-time health monitoring and early warning. For instance, smart bracelets can identify cardiovascular disease risks at early stages through heart rate variability analysis [22]. A study targeting older adults demonstrated that abnormal heart rate events detected by wearable devices significantly correlated with cardiovascular event incidence [42]. Furthermore, AI-driven diagnostic models enhance diagnostic accuracy by integrating multidimensional data. The application of these early diagnostic technologies offers powerful tools for early detection and intervention in health issues among the aging population.

6.2 Treatment strategies of medical technology in health management for the aging population

The application of medical technology provides diverse treatment strategies for health management in the aging

population. Tele-rehabilitation technology assists older adults in home-based rehabilitation training through video guidance and real-time monitoring. For example, the “iREAP” project significantly improved frailty status in older adults by integrating rehabilitation and empowerment programs [43]. This project included 99 participants, demonstrating significant improvements in both balanced ability and quality of life. Additionally, digital medication management systems enhance medication adherence among older adults through smart reminders and medication monitoring [44]. A study on older adults with diabetes demonstrated that health education incorporating digital medication management significantly reduced hypoglycemia incidence [18].

Advancements have been achieved in the application of VR technology for pain management. For instance, VR simulations of relaxing environments significantly reduce pain scores in older chronic pain patients [23]. Moreover, social robots in psychotherapy alleviate depressive symptoms in older adults through interactive communication [25]. These treatment strategies enhance therapeutic outcomes while improving treatment adherence and quality of life for older adults via personalized and intelligent approaches.

6.3 Personalized intervention measures for health education in the aging population

Personalized interventions represent a core trend in health education for the aging population, requiring integration of individual characteristics and health needs. Stratified education based on health literacy stands as one crucial approach. For instance, employing visually rich educational materials combined with face-to-face guidance for older adults with low health literacy has significantly improved their health knowledge acquisition rates [45]. Furthermore, personalized interventions grounded in behavioral theories analyze individual motivations and barriers to develop targeted educational programs. A study targeting hypertension patients demonstrated that personalized education incorporating self-efficacy theory significantly improved their blood pressure control rates [4].

Personalized interventions through interdisciplinary collaboration also demonstrate advantages. For instance, multidimensional interventions combining nutrition, exercise, and psychology significantly improved glycemic control in older adults with diabetes [13]. Additionally, personalized recommendation systems based on big data analyze user behavior and health data to provide customized health advice [24]. The application of these personalized intervention measures not only enhances educational effectiveness but also increases engagement and adherence among older adults by addressing individual needs.

7 Future prospects

This review did not conduct any original research, and all ethical issues discussed are derived from the cited literature. Ethical controversies in health education for the aging population primarily involve privacy protection, informed consent, and technological fairness. Privacy protection stands as a core issue, as the widespread application of digital health technologies has heightened the risk of personal health data

leakage. A survey targeting older adults revealed that 62% of participants expressed concerns about potential misuse of their health data [15]. Furthermore, the validity of informed consent faces challenges, as some older adults, due to cognitive decline or insufficient digital skills, struggle to fully comprehend the risks and benefits associated with technological applications [46]. For instance, smart bracelets' real-time monitoring function may infringe upon older adults' privacy, though some users remain unaware of this risk [14].

Technological fairness constitutes another significant ethical concern. The Digital Divide prevents some older adults from accessing technology-enabled educational resources. Chinese research indicates only 38.6% of older adults utilize the Internet for health information, with even lower adoption rates in rural areas [20]. Furthermore, algorithmic bias may cause inequitable distribution of personalized education content, exemplified by insufficient resources for older adults with limited education [47]. These ethical controversies must be resolved through policy regulations and technological optimization to ensure equitable and secure health education for the aging population.

Challenges in applying medical technology to education for the aging population include technological adaptability, user acceptance, and resource integration. Technological adaptability represents a core challenge, as current digital tools often inadequately address the physiological and cognitive characteristics of older adults. For instance, complex interfaces in smartphone applications hinder operation for some older adults [21]. An online walking program for retired older adults showed that 40% of participants discontinued use due to interface complexity [14]. Furthermore, user acceptance is limited by digital literacy and trust factors. A study in China shows that older adults aged over 55 exhibit significantly lower acceptance of digital health technologies [15].

Resource integration also poses a significant challenge, as the fragmentation of medical technology and educational resources results in inefficient service delivery. For instance, inadequate integration of remote monitoring data with clinical systems hinders personalized delivery of educational content [6]. Additionally, insufficient cross-sector collaboration leads to a disconnect between health education and medical services [48]. These challenges must be addressed through technical optimization, user-centered design, and policy support to enhance the effectiveness of medical technology in science-based education for the aging population.

The future development of science-based education for the aging population will advance toward individualized, intelligent, and interdisciplinary collaboration. Personalized education will leverage big data and AI technologies to achieve targeted delivery of educational content. For example, analyzing users' health data and behavioral characteristics enables the provision of customized health advice [24]. The application of intelligent technologies will further enhance educational interactivity and effectiveness; for instance, combining VR simulation scenarios with social robots provides immersive educational experiences for older adults [7].

Interdisciplinary collaboration will emerge as a significant

trend, integrating resources from medicine, pedagogy, sociology, and other fields. For instance, collaborations between community health centers and universities enable student volunteers to provide personalized educational guidance to older adults [17]. Furthermore, policy support will advance the proliferation of science-based education, exemplified by government-funded digital skills training programs that improve technology adoption among older adults [49]. Moving forward, science-based education for aging populations will attain healthy aging objectives via technological innovation and cross-sector collaboration, providing solutions to global demographic aging challenges.

Author contributions

Yan Han contributed to conceptualization, methodology, writing original draft, visualization, and funding acquisition; Linyu Zhang contributed to data curation, investigation, software, and validation; Ling Teng contributed to formal analysis, investigation, resources, and writing-review and editing; Hanxu Xie contributed to methodology, software, validation, and writing-review and editing; Ruixuan Zhang contributed to data curation, investigation, and visualization; Jinwu Liu contributed to formal analysis, resources, and validation; Wei Su (corresponding author) contributed to conceptualization, project administration, supervision, writing-review and editing, and funding acquisition. All authors reviewed and approved the final manuscript.

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Conflict of interests

The authors declare that they have no conflicts of interest.

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